THE

CIRCLE

OF

THE MECHANICAL ARTS.

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THE MECHANICAL ARTS;

CONTAINING

PRACTICAL TREATISES

ON THE VARIOUS

MANUAL ARTS, TRADES, AND MANUFACTURES.

By THOMAS MARTIN, Civil Engineer,

ASSISTED BY EMINENT PROFESSIONAL MECHANICS AND MANUFACTURERS.

Illustrated by numerous Engravings.

SECOND EDITION.

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PREFACE.

THE work now presented to the public, in its complete form, will, it is presumed, recommend itself to general attention, as well from its novelty as from the importance of the subjects of which it treats. Of all the numerous Dictionaries of Arts and Sciences published in this country, there is no one that bears any resemblance to "the Circle of the Mechanical Arts."

In France, indeed, there have been works of the same kind, but they are all executed on too large a scale to become generally useful; and, by their price, they are necessarily confined to the libraries of the rich, or to the repositories of the learned, which have been founded and maintained at the public expense. Those for whom such works are chiefly adapted, can rarely obtain even a sight of them, and they are thus almost entirely destitute of that utility in improving the arts and manufactures, for which they were naturally designed. Hence has arisen the difficulty and those obstacles which the editor of this volume has met with in seeking information on the various topics that have come under discussion. In almost all instances he has found persons engaged in trade extremely unwilling to communicate the processes and manipulations which distinguish their several arts; and, in the course of his inquiries, he had frequently to regret that those who were most disposed to afford him assistance were, from want of all literary habits and practice, utterly incapable of rendering him that aid which he could have hoped for by the communication of their ideas in writing. Many persons refused him help lest they should be thought to betray the secrets of their trade, and others were equally reluctant to enter into the nature of their profession, fearing that a free communication of their own thoughts would expose their ignorance of its principles, or would prove that its excellence did not depend upon any thing secret, or that could be concealed.

Without, however, troubling the reader with a further enumeration of the difficulties which have beset the editor in his pursuits, and impeded his progress in the attainment of

 practical

practical knowledge, he will proceed briefly to state some peculiar features of the work which he has, notwithstanding the hinderances thrown in his way, at length, accomplished.

The "Mechanical Exercises," published by Moxon, more than a century ago, have become exceedingly scarce: in some respects, it has been the wish of the editor of the "Circle" to follow the example set him by his precursor, yet he has been ambitious of surpassing him in the extent and variety of information contained in his book. Mr. Moxon treated almost exclusively of the arts and trades connected with building; the editor of the Circle, disdaining so limited a plan, has taken a much more extensive range, and included, in his work, practical treatises on a great variety of other manual arts, trades, and manufactures.

The attention of the reader is particularly directed to the long and elaborate article on CARPENTRY, which forms so large a proportion of the volume, and which, it is presumed, will be found the most complete treatise ever published on the subject. No expense has been spared to illustrate this article by numerous engravings. The other articles connected with building, viz., SAWING and PLANING, BRICK-making and BRICK-laying, SLATING, PLASTERING, PLUMBING, PAINTING and GLAZING; and TURNING, which is common to many branches of trade, will be found under their respective heads; as well as the more general treatises of ARCHITECTURE, and MASONRY.

Among the useful and important manipulations common to every individual, as well as to people in distinct trades, will be found, in the alphabetical order, BAKING and BREWING, with such rules and recipes as will shew that the convenience of private families have been consulted equally with the interests of those who manufacture on a large scale for the public.

In the arts connected with, or depending upon, or, at least, which are materially benefited by the principles of modern Chemistry, may be mentioned, DYEING, and HAT-making; GLASS-making; POTTERY, including the manufacture of PORCELAIN; SOAP-making; STARCH-making, and TANNING; also RECTIFICATION and DISTILLATION, both included under the former term.

Of the manufactures carried on to a vast extent in several of the large towns in the northern parts of England, as Manchester, Sheffield, and Birmingham, the reader may be referred to COTTON-

COTTON-manufacture and WEAVING; BUTTON-making, and CUTLERY; to the manufacture of FILES and NAILS, and to WIRE-drawing. To these may be added, the manufacture of GUNS and SHOT, which trades are carried on upon an extensive scale at Birmingham, though the best warranted guns are said to be the production of London workmen, to one of whom, eminent in his profession, the editor, as has been acknowledged in the article, is indebted for the facts contained in his account of the business.

Ship-building was reckoned too extensive an article for a work to be comprised in a single volume, and has been omitted; nevertheless, the manufacture of BLOCKS and ROPES, connected with it, has been rather fully treated of.

The trades, on which the literature of the country depends, will be found in their respective places, as PAPER-making; PRINTING, by moveable letters, and on the stereotype plan; and BOOK-binding: to these may be added another branch of business, not indeed connected with books, but of which paper is the staple commodity, viz., STAINING of Paper, chiefly used in the decoration of our apartments. Hence we have been led to treat of other branches of business not absolutely necessary to the convenience of life, but which are found in every stage of improved society, such are COACH-making, with which is allied the Wheelwright; ENAMELLING; CARVING,* and GILDING; GOLD-beating; JAPANNING; ENGRAVING, and the STAINING of Glass, found under the articles Glass and Glazing.

To the public it was a matter of importance that a full article should be given on WATCH and CLOCK-making; this has been done, including a description of all the tools used in the art, and of the facts which led to the invention, and of the principles on which these useful instruments depend.

The COOPER, the COMB-maker, the CURRIER, and the BASKET-maker, will perceive that considerable pains have been taken to collect and diffuse information respecting the trades which they practise, and which are exceedingly useful in domestic life; some, indeed, not only on their own account, but for the aid which they afford to other manufacturers.

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* By mistake, a figure is referred to in this article, which was not intended to be engraved; and in the article BRIDGES, page 41, references are erroneously made to *Plate* II, which was not necessary to illustrate the subject.

To

To the article ENGINEERING, we may call the attention of our readers, being, if we mistake not, wholly omitted in Cyclopedias; and, as connected, in some measure with it, we may point out MINING; and FOUNDING, in all its different branches, from the grosser metals to the coining of gold and silver money.

As the Mechanical Arts depend much upon the principles of GEOMETRY, we have, by way of Appendix, given a treatise on the practical parts of that science.

Upon the whole, we may recommend the Circle of the Mechanical Arts to persons of various classes and ranks in life; as to GENTLEMEN who are fond of mechanical pursuits, or, who, for amusement, superintend the works going on upon their own estates, or, who wish to be informed of the manufactures established in their own neighbourhood, or which they may meet with in their travels. It will likewise be found extremely useful to persons engaged in trade; to youths apprenticed to learn the arts described; as well as to practical mechanics in general.

Finally, the editor throws himself upon the candour of the public; he does not presume that he has performed all that every reader will expect to find, but he is confident that much is done, and that the favour which he has experienced during the publication of his work in separate parts, will be augmented now the publication is completed.

It was originally intended to have given a *Second Part*, chiefly as a Dictionary of Terms, assimilating itself to other Dictionaries; but, at the desire of many of his subscribers, the Editor has confined the work to its present extent.

LONDON,
March 25, 1813.

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ARCHITECTURE.

Architecture is the art of planning and erecting buildings of any kind, as churches, palaces, temples, dwelling-houses, bridges, &c.

It has been too generally imagined, that the study of Architecture is of little or no use to any persons, but those who are immediately concerned in building; nothing, however, can be more erroneous than such an idea, as there is scarcely any profession in which it is not, directly or indirectly, of the greatest importance. The knowledge of its beautiful proportions and ornaments, has given to many of the articles manufactured in this country a great superiority over those of any other nation. The proper application of its ornaments, aided by chemistry, enabled our ingenious countryman, Mr. Wedgwood, to carry the porcelain manufacture to a perfection and elegance, till then unknown in Europe; affording a sufficient proof, if proof were wanting, of the utility this art may be of in professions at first sight wholly unconnected with it. The smith, the cabinet-maker, the turner, the founder, and in short every workman who has to give form to rude materials, will find it highly advantageous to devote a portion of his time to the acquirement of this sublime and useful art.

It being our intention in the present work to treat only of the practical part of the arts, it will not be necessary for us to enter largely into the history of Architecture. We shall content ourselves, therefore, with pointing out such circumstances as will account, in some measure, for the origin of, and the striking peculiarities which mark the different orders. It is a very natural supposition, that in climates, where rain seldom falls, it is unnecessary to guard so carefully against the inconveniences which attend exposure to the atmosphere, as in those more subject to wet. The primitive habitations, therefore, it is probable, were constructed with flat roofs, which were nothing more than poles laid from one tree to another, and covered with such materials as nature most readily presented, as brushwood, turf, leaves, or grass; these affording a sufficient protection in those delightful climates, where Architecture first had its origin. As population increased, and agriculture improved, it became necessary for the inhabitants of woods to seek situations in the open country, more favourable to their occupations; hence other means for constructing habitations became necessary, and men finding the advantages of living in society, began to erect habitations of stone. These improvements being but gradual refinements on their rude huts, carried with them a portion of the character, which necessity, or rather convenience, first suggested. We may, therefore, conclude that the trunks of trees, set upright at proper distances, first gave the idea of a range of columns; whilst the bands or rings placed round them to prevent them from splitting, and a flat stone at the top and bottom to carry off the rain, and to give them a more solid bearing, may sufficiently account for the origin of the capital and base. The materials which constituted the covering, and which it is probable projected, and were laid on of a considerable thickness,

bear some resemblance to the entablature. The origin of the pediment is more obvious, having nearly the same offices assigned to it as gave it birth, namely, the angular or rising roof.

These observations on the origin of the column and entablature, are made with a view that all those who study architecture, may know the uses for which the different parts were originally intended. Though many of these have ceased to be necessary from the various improvements in the art, and others are so ornamented as to conceal their original design—it must never be lost sight of, that each member had originally its uses, which will prevent errors by the indiscriminate misapplication of them.

Most persons who have written on architecture, agree that the Greeks had their first ideas respecting it from the Egyptians. The latter, long before it was practised with any thing like order in Greece, had made considerable progress towards its perfection; but, though their works were grand, they were deficient in delicacy and taste. It was reserved for the Greeks to impart to this art elegance and symmetry, and to unite with these comfort and convenience. What we have said respecting the origin of Grecian architecture, may account for the peculiar character of the Arabian, Chinese, and what is commonly called Gothic. The last is the common appellation by which the architecture of the middle ages, is known. In the Arabian mosque, we cannot but see the strong resemblance it bears to a number of small bell tents, encircling a larger one. The caravansary is a court surrounded by small tents, each having its own dome, to which the Greek church of St. Sophia, at Constantinople bears a striking similitude. The Chinese architecture appears to be derived from the construction of wooden buildings; and Sir George Staunton informs us, that the roofs are of the same shape as the cover of a square tent. Thus we may trace the different stiles of architecture to the formation of primitive huts; which were constructed so as best to afford the purposes of shelter or shade, as the climate in which they were erected demanded; and of the most abundant and best calculated materials to answer these ends. We must therefore look to these sources, if we wish to obtain a just idea of the origin of stiles, differing so widely from each other.

The architects who built most of the cathedrals in Europe, departed from the stile of Greece and Rome, and introduced another, in which arcades made the principal feature. Not finding in every place quarries, from which blocks could be raised of sufficient size for forming the far projecting cornices of the Greek orders, they relinquished these proportions, and adopted a style of ornament which did not require such projections. By substituting arches for the horizontal architrave or lintel, they were able to erect buildings of a vast extent, and with spacious openings, using only small pieces of stone. The form adopted for a christian temple occasioned many intersections of vaultings, and multiplied the arches exceedingly. Constant practice afforded opportunities of giving all possible variety to these intersections, and taught the art of ballancing arch against arch in every situation. In process of time arches became principal ornaments, and a wall or a ceiling was not thought properly decorated, until it was filled with mock arches, crossing and cutting each other in every direction.

We call the middle ages rude and barbarous, and give to their style of Architecture the appellation of Gothic; but there was surely much knowledge in architects, who could execute such magnificent and difficult works as they have left us. More appropriate appellations for these species of Architecture, would be *Saxon* and *Norman*, so far as relates to buildings of this kind in Britain; the Saxon being distinguished by the circular, and the Norman by the pointed arch; for, under the guidance of these respective nations, each kind displayed its grandeur and peculiarites in the greatest perfection. The architects of whom we now speak, do not appear to have studied the theory of equilibriated arches. For a long period, they adopted an arch which was very strong, and permitted considerable irregularities of pressure, namely, the pointed arch. The very deep mouldings with which this arch was ornamented, made the arch-stones very long in proportion to the span of the arch. They had, however, studied with great care the mutual thrust of arches on each other; and they contrived that every invention for this purpose should become an ornament, as well as a necessary part of the building. Thus we frequently see small buildings having buttresses on the sides. These buttresses are necessary in a large vaulted building, for withstanding the outward pressure of the vaulting; but they are useless when there is a flat ceiling. Pinnacles on the heads of buttresses are now considered as ornaments; but, originally, they were put there to increase the weight of the buttresses. Even the great tower in the centre of a cathedral, which now constitutes its chief ornament, is a load almost indispensably necessary, for enabling the four principal columns to withstand the combined thrusts of the aisles, the naves, and the transepts. In short, the more closely we examine the ornaments of this style of Architecture, the more shall we perceive that they are essential parts; and the more we consider the whole style, the more clearly shall we see, that it is all deduced from the relish for arcades indulged to extremes, and pushed to the utmost limit of possibility in the execution. This pure Gothic was followed by a middle stile, in which the Grecian and Gothic were blended together. Although the Grecian did not become prevalent in England, until the time of Inigo Jones, yet there existed some specimens of it long prior to his day. Perhaps the earliest was Somerset-house, in the Strand, built in 1549. Towards the end of the 15th and beginning of the 16th centuries, learning and the chaste architecture

ture of the Greeks and Romans began to revive: It first dawned in Italy; and its revival may be attributed to the remains of those magnificent structures which were to be found in that country. From thence an improved method of building was gradually introduced into all parts of Europe; and although the Italians for a long time retained the superiority over the other European nations as architects, yet as men of genius from all quarters constantly visited Italy, for the purpose of improvement in this, as well as in the other arts, they were in the course of time equalled, if not surpassed, by the architects of other nations, and even by those of our own country.

The *orders* as now executed by architects, are *five*, viz. the *Tuscan*, the *Doric*, the *Ionic*, the *Corinthian*, and the *Composite*, which are distinguished from each other by the column, with its base and capital, and by the entablature. The Tuscan and Composite orders are rejected by many, because they differ but little from the other three, either in their ornaments, or in the offices assigned to them. The Tuscan resembling the Doric, deprived of some of its mouldings; and the Composite differing from the Corinthian only, by the introduction of the Ionic volute into its capital. The Tuscan order is characterized by its plain and robust appearance; and is, therefore, used only in works where strength and plainess are wanted; it has been introduced with great effect and taste in that durable monument of ancient grandeur, the Column of Trajan, at Rome. Indeed, general consent has established its proportions, for such purposes, to be beyond all the other orders. The *Doric* possesses nearly the same character for strength as the Tuscan, but it is enlivened by its peculiar ornaments, the triglyph, mutules, and guttæ or drops, under the triglyph; these decorations characterize the Doric order, and in part are inseparable from it. Its proportions recommend it where united strength and grandeur are required. The *Ionic* partakes of more delicacy than either of the former, and is on that account as well as on account of its origin, called feminine, and not improperly supposed to have a matronly appearance. It is composed of a medium between the masculine strength of the Tuscan and Doric, and the slenderness of the Corinthian. The boldness of the capital, with the beauty of the shaft, makes it eligible for porticos, frontispieces, entrances to houses, &c. Dentiles were at first added to the cornice of this order. The *Corinthian* possesses more delicacy and ornament than either of the other orders; the beauty and richness of the capital, and the delicacy of the shaft, render it the most suitable in those edifices where magnificence and elegance are required. On this account it is frequently used for the internal decoration of large state rooms, in which it has a chaste appearance, though at the same time beautiful and superb. The *Composite* order is the same as the Corinthian in its proportions; and these two orders are nearly alike in their ornaments. The addition of the modern Ionic volute to the capital, gives it a bolder projection. It is applicable in the same manner, and in the same cases as the Corinthian.

General principles of Architecture. When about to build, choice of situation is the first thing to be considered. For dwelling houses, a spot should, if possible, be chosen sufficiently elevated to be free from damps and noxious vapours, and at the same time sheltered from the severity of winter. The neighbourhood of fens, and stagnate waters, should always be avoided. It should be a spot where water can be conveniently procured; where drains may be made with facility and with a proper fall; and where the principal apartments may have the advantage of southern and western aspects. The nature of the soil should likewise be examined, either by means of borers or by sinking holes, in order to ascertain if a firm foundation can be had. Stony or gravelly soils generally afford the best foundation; yet these are sometimes deceitful, for underneath, layers of gravel, large cavities, or earth of a loose and hollow substance, have frequently been found. In order to detect such deceptions, a celebrated Italian architect has recommended that great weights should be forcibly thrown on the ground, so that by attentively listening to the sound, some idea may be formed of its firmness or hollowness. A foundation of sand is proverbially bad; marshy, rotten, or boggy ground is equally insecure, and can only be built upon by piling, planking, laying large ledges, &c. In building near the water, great care should be taken to ascertain the depth of the soil to the very bottom; and this caution should likewise be well attended to, when the ground has been wrought or dug before, or when it has been lately formed by accumulated earth or rubbish.

The situation being chosen, the attention of the architect should next be directed to the form of the proposed edifice, together with the arrangement of the different apartments it is intended to contain. A plan should be made with an elevation of each front, and also two or more sections. If the building be a considerable one, it would be advisable to have a perfect model formed with all its minute parts; and that the judgment may not be prejudiced, the model should be made plain, without colours or other beautifying. As the number and distribution of the rooms must depend on the establishment, and mode of living of the employer, the following observations can only be considered as general hints. Utility and external appearance should, undoubtedly, as far as possible, be combined; but in dwelling houses, very little of the former should be sacrificed to the latter. It is generally desirable to divide the principal front into three parts; a centre, and two wings. The centre should not appear of too great a magnitude for the wings, nor the wings too magnificent for the centre. The parts should bear a pleasing proportion to each other, both when separately considered, and unitedly. A pyramidical form generally produces a happy effect;

effect; but the choice of the external appearance must depend much on the situation, adjacent scenery &c. &c. Boldness and simplicity should be distinguished from heaviness or poverty; lightness and elegance from frippery and whimsicality. Buildings intended solely for utility, ought in every part to correspond precisely with that intention. The least deviation from use, though contributing to ornament, will be disagreeable; for every work of use being considered as a mean to an end, its perfection as a mean is the most important consideration, and every thing in opposition to that, is to be neglected as improper. On the other hand, in buildings intended solely for ornament, as columns, obelisks, triumphal arches, &c. beauty alone ought to be regarded. The principal difficulty in architecture lies in combining use and ornament. In order to accomplish these ends, different and even opposite means must be employed, and this is the reason why they are so seldom seen united in a due degree. Hence, in all buildings, the only practicable method is to prefer utility or ornament, according to its character; in palaces, and such buildings as admit of a variety of useful contrivances, regularity ought to be preferred; but in dwelling houses that are too small for variety of contrivance, utility ought to prevail; regularity being neglected as far as it stands opposed to convenience.

The proportions of doors are determined by the uses for which they are designed. The door of a dwelling house, which ought to correspond to the human size, is confined to seven or eight feet in height, and three or four in breadth. Doors of entrance vary in their dimensions according to the height of the story, or according to the magnitude of the building, in which they are placed. In private houses, four feet may be the greatest width, and in general three feet will be sufficient, except under some peculiar circumstances. A good proportion for doors is that in which their dimensions are in the ratio of three to seven, in small doors, and one to two in large doors. Double doors, with sufficient room between to allow of the one being shut before the other is opened, will contribute much to keep up an equal temperature through the house, especially where the lobby is warmed by a stove. In the entrance doors of public edifices, where there is a frequent ingress and egress of a multitude of people, their width may be from six to twelve feet. Inside doors should in some measure, be regulated by the height of the stories; this, however, has its limit, as there is a certain dimension which ought not to be exceeded, for the difficulty of shutting the door will be increased by its weight; therefore doors for private edifices, which are intended to be shut with one close, should never exceed three feet six inches in breadth. In palaces, and in the houses of noblemen, where much company resort, all the doors are frequently thrown open; these may be much larger than those of inferior edifices; and their width may be from four to six feet. In modern houses, it is common to have large folding doors for throwing two rooms into one; in such cases, the proportion of the aperture will often be of a less height than that of twice the breadth, as the doors in the same story are generally one height throughout. The lintels of doors should range with those of the windows, and their breadth should never be less than that of the windows. In the fourth book of Vitruvius, rules are laid down for Doric, Ionic, and Attic doors, all of which have their apertures narrower at the top than at the bottom, in conformity to those which are seen in the ruins of ancient Greek and Roman edifices; as in the temple of Minerva Polias, at Athens, and the temple of Vesta at Tivoli. Doors of this form have the property of shutting themselves, which reason, probably, occasioned their invention; they have been introduced by a few modern architects, particularly Mr. Soane, in the Bank of England. As to the situation of the principal entrance, it is evident that the door should be in the middle, as it will not only contribute better to symmetry, but will communicate more readily with all the other parts of the building. Where the internal arrangement of the rooms is injured by the door being in the center of the front, a blank door or window, having the appearance of a door, should be substituted, and the entrance made where it is more convenient The apertures of exterior doors in blank arcades, are generally placed at the same height as the springing of the arch; or if they have dressings, the top of the dressing, whether it be the architrave or cornice, is generally placed on the same level with the impost. The most common method of adorning the aperture of a door is with an architrave surrounding it; or with a cornice surmounting the architrave; or with a complete entablature. Sometimes consoles are introduced, flanking the architrave jambs, and sustaining the ends of the cornice. Sometimes the architrave jambs are flanked with pilasters of the orders, or of some analogical form, in which case, the projections of their bases and capitals are always less than that of the surrounding architrave; and the architrave over the capitals of the pilasters is the same with that of the head of the door. Sometimes the door is adorned with one of the five orders. The entrance doors of grand houses are frequently adorned with porticos, after the manner of Grecian temples.

With regard to windows, the first considerations are their number and their size. They must be so arranged, as to admit neither more nor less light than may be requisite. In the determination of this subject, regard must be had to the climate, the aspect, the extent, the elevation of the building, and its destination, and also to the thickness of the walls in which the windows are to be placed; on this circumstance will partly depend the greater or less quantity of light that will be admitted. Where the walls are thick, as they commonly are in stone buildings,

buildings, the windows should have a considerable splay on the inside, which will admit almost as much light, as if the windows were externally of the same size with the increased internal dimensions.

Sky lights are sometimes used to light stair-cases, but unless they are made with great care, they are very subject to leak, in a country like ours where so much rain and snow falls; when they are introduced for stairs, they ought to be double, with a large space between; otherwise they contribute greatly to render houses colder, because they form uneasy communications between the internal warm, and the external cold air. In hot countries, where the sun is seldom clouded, and where its rays dart more intensely upon the earth, the light is stronger than in those which are temperate or cold; therefore, a smaller quantity of it will suffice, and more than a sufficiency should not be admitted, as the consequence would be the admission of heat. The same happens in respect to a southern aspect, which receives more heat, and consequently more light, than a northern, or even an eastern or western one. A large lofty space requires a greater quantity of light then one circumscribed in its dimensions; and art demands, that the quantity introduced should be so regulated, that it may excite gay, cheerful, or solemn sensations, in the mind of a spectator, according to the nature and purposes for which the structure is intended.*

Wherever sun-shine predominates, light must be admitted and distributed with caution, for where there is an excess of light, the heat becomes dreadfully incommodious to the inhabitant, and injurious to the furniture. In Italy, and some other hot countries, although the windows in general are less than ours, their apartments cannot be made habitable, but by keeping the window shutters almost closed, while the sun appears above the horizon. But in regions where clouds prevail eight months in the year, it will always be right to admit a sufficiency of light, to counteract the gloom of wet and cloudy seasons, and have recourse to blinds or shutters whenever the appearance of the sun renders it too abundant.

The proportions for the apertures of windows depend upon their situation. Their width in all the stories must be the same; but the different heights of the apartments, make it necessary to vary the height of the windows likewise. In the principal floor it may be from two and one eighth of the width, to two and one third, accordingly as the rooms have more or less elevation. In the ground story, where the apartments are lower, the apertures of the windows seldom exceed a double square, and when they are in a rustic basement, they are frequently made much lower. The height of the windows of the second floor may be from one and a half of their width, to one and four-fifths; and attics and mezzanines may be either a perfect square, or somewhat lower.

The windows of the principal floor are generally most enriched. The simplest method of adorning them, is, with an architrave surrounding the aperture, and crowned with a frieze and cornice. The windows of the ground floor are sometimes left entirely plain, without any ornament, and at others they are surrounded with rustics, or a regular architrave, with a frieze and cornice. Those of the second floor have generally an architrave carried round the aperture; and the same method is adopted in adorning the attic and mezzanine windows; but the two last have seldom either frieze or cornice, whereas the second floor windows are often crowned with both. The breasts of all the windows on the same floor should be on the same level, and raised above the floor from two feet nine inches, to three feet six inches, at the most. When the walls are thick, the breasts should be reduced under the apertures, for the conveniency of looking out. When the building is surrounded with gardens, lawns, or other beautiful objects, the French method of continuing the windows quite down to the floor, renders the room exceedingly pleasant; but when this mode is adopted in close streets, where it contributes to nothing but rendering houses colder, it is truly ridiculous. The intervals between the apertures of windows, depend in a great measure on their enrichments. The breadth of the apertures is the least distance that can be between them; and twice that breadth should be the largest in dwelling-houses; otherwise the rooms will not be sufficiently lighted. The windows in all the stories of the same aspect must be placed exactly above one another. The mathematical rule of apportioning light to rooms, is as follows;—multiply the length of the room by the breadth, and multiply the height by the product of the length and breadth; and out of that product extract the square-root, which is the light required. For example, suppose a room to be forty feet by thirty, and the height sixteen feet, the square-root will be 138 feet four inches; which may be divided into four windows, and each window will contain 36 feet, superficial. The height of each of these windows will be 9 feet, and the width 4 feet. Suppose a room to be 36 feet by 24, and 15 feet in height, the square-root will be 113 feet; which divided into four parts, or windows, will give 28 feet three inches to each window. The height of these windows will be 8 feet six inches, and the width 3 feet four inches; and so for any others by the same rule of proportion. Steps of stairs should likewise be accommodated to the human figure, without regarding any other proportion; they

* We cannot but regret the influence the window tax has on the appearance of most of our modern houses; which are not only less beautiful, but for want of a sufficient number of these necessary apertures, are rendered less comfortable and healthy to the persons inhabiting them.

they are accordingly the same both in large and small buildings. In sumptuous buildings, the steps should not be less than four, nor more than six inches high; not more than eighteen, nor less than twelve inches broad; nor less than six feet, nor nor more than fifteen feet long. In ordinary houses they may be somewhat higher and narrower, and they must be much shorter in general, but eight or even seven inches is too high for an easy ascent, and they ought never to be less then nine or ten inches broad, nor shorter then three feet. The steps should be laid somewhat sloping, or a little higher behind, which is formed to lessen the labour of ascending.

(*See more of this in the articles* CARPENTRY *and* JOINERY.)

We come now to consider the form of the building. A cube or square, is a more agreeable figure than an oblong, or parallelopipedon. This constantly holds good in small figures; but a large building in form of a cube, is lumpish and heavy; therefore an oblong form is always preferred for dwelling houses. Care should, however, be taken to avoid making the plan longer than necessary, as there will be great waste in the passages, and considerable difficulty in lighting them.

With regard to the internal divisions, it is found more convenient that the rooms should be rectangular, to avoid useless spaces. An hexagonal, or six sided figure leaves no void spaces; but it determines the rooms to be all of one size, which is both inconvenient and disagreeable for want of variety. Though a cube be the most agreeable figure, and may answer for a room of moderate size; yet, in a very large room, utility requires a different form. The best form for a long room, is that of a parellelogram, and this figure is also best calculated for the admission of light; because, to avoid cross lights, all the windows ought to be in one wall; and if the opposite wall be at such a distance as not to be fully lighted, the room must be obscure. Dining rooms should be so situated, as to give an easy access to servants who wait at table; and the fireplace so placed as to warm the room uniformly. In the building of chambers, regard ought to be had, as well to the place of the bed, which is generally six or seven feet square, and the passage, as to the situation of the chimney, which for this consideration ought not to be placed just in the middle, but distant from it about two feet, or two feet six; this, however, will be unnecessary in very large bed-chambers. The height of a room, exceeding nine or ten feet, has little relation to utility; therefore proportion is the only rule for determining the height, when above that number of feet. Artists, who deal in the beautiful, love to entertain the eye; palaces and sumptuous buildings, in which grandeur and beauty may be fully displayed, give them an opportunity of shewing their taste. But such a propensity is peculiarly unhappy with regard to private dwelling-houses; because in these, utility cannot be sacrificed to magnificence, without hurting their intrinsic worth. There is no opportunity for great variety of form in a small house; and in edifices of this kind, internal convenience has not, hitherto, been happily adjusted to external regularity. Perhaps an accurate coincidence in this respect is beyond the reach of art. Architects, however, constantly split upon this rock, for they never can be persuaded to give over attempting to reconcile these two incompatible objects; how otherwise should it happen, that of the endless variety of private dwelling-houses, there should not be one found that is generally agreed upon as a good model? The unwearied propensity to make a house regular as well as convenient, obliges the architect, in some instances, to sacrifice convenience to regularity, and in others, regularity to convenience; and accordingly the house which turns out neither regular nor convenient, never fails to displease.—Nothing can be more evident, than that the plan of a dwelling-house ought to be suited to the climate; yet no error is more common than to copy in Britain the form of Italian houses, not forgetting even those parts that are purposely contrived for collecting air, and for excluding the sun; witness our collonnades and logies, designed by the Italians to gather cool air, and exclude the beams of the sun; conveniences which the climate of this country does not require.

We shall next view architecture as one of the fine arts; which will lead us to the examination of such buildings, and parts of buildings, as are calculated solely to please the eye. Variety prevails in the works of nature; but art requires to be guided

* All precautions to prevent the communication of sound to the bed rooms, should be taken. To this end it is advisable to fill the space between the joists of the floor, above the bed room, with saw-dust, which must be sustained by short pieces of board, nailed against the joists, above the ceiling of the lower apartment. In the distribution of rooms for servants we can only consult the facilities, of our general plan, and, if possible, to give every bed room a fire place. There are two things to be attended to in the situation of the kitchen, first to place it as near the dining apartment as possible: secondly to contrive it so that the effluvia from the cooking, shall not enter the dining-room through the passage, which should always be a covered one. In town houses it is generally most convenient to place the kitchen beneath the parlour floor; to prevent the lighter, warmed air charged with the smell from cooking, rising into the dining rooms; a seperate funnel like the kitchen chimney, carried up in the same stack, will always afford a remedy. A communication with this flue must be made by means of an opening in the ceiling of the kitchen, this opening may be closed by a door, when nothing is going on in the kitchen to occasion an unpleasant smell. In every modern house of respectable size water closets are introduced, which of course are situated so as to be convenient to the whole of the house, and at the same time as much concealed as circumstances will admit of; water closets are now so much improved, that they may be placed in any part of the house, without the least danger of any unpleasant smell; this, is in a great measure effected by means of pipes, bent down, so as to form an elbow, in the lower part of which, the last portion of water which is thrown down lodges, and completely prevents any effluvia from rising. This contrivance is equally applicable to drains, which will be treated of in their proper places. Care should be taken to prevent the water in the pipes from freezing, by keeping them from the influence of the external air, as it would most infallibly burst them.

ed by rule and compass. Hence it is, that in such works of art as imitate nature, as in laying out pleasure grounds, planting, &c. the great aim shonld be to hide every appearance of art, which is done by avoiding regularity, and indulging variety. But in works of art that are original, and not imitative, such as architecture, strict regularity and uniformity ought to be studied, as far as consistent with utility.

Proportion is not less agreeable than regularity and uniformity; and, therefore, in buildings intended to please the eye, they are all equally essential. It is taken for granted by many writers, that in all the parts of building there are certain strict proportions which please the eye, in the same manner as in sound, there are certain strict proportions which please the ear; and that in both the slightest deviation is equally disagreeable. But it ought to be considered, that there is no resemblance or relation between the objects of different senses. What pleases the ear in harmony, is not the proportion of the strings of the instrument, but of the sounds which these strings produce. In architecture, on the contrary, it is the proportion of different quantities that pleases the eye, without the least relation to sound. Perrault in his comparison of the ancients and moderns, goes to the opposite extremes, maintaining that the different proportions assigned to each order of columns are arbitrary, and that the beauty of these proportions is entirely the effect of custom. But he should have considered, that if these proportions had not originally been agreeable, they could never have been established by custom.

For illustrating this point, we shall add a few examples of the agreeableness of different proportions. In a sumptuous edifice, the capital rooms ought to be large, otherwise they will not be proportioned to the size of the building; for the same reason a very large room is improper in a small house. But in things thus related, the mind requires not a precise or single proportion rejecting all others; on the contrary, many different proportions are equally agreeable. It is only when a proportion becomes loose and distant, that the agreeableness abates, aud at last vanishes. Accordingly, in buildings, rooms of different proportions are found to be equally agreeable, even where the proportion is not influenced by utility. With regard to the proportion the height of a room should bear to the length and breadth, it must be extremely arbitrary, considering the uncertainty of the eye as to the height of a room, when it exceeds 16 or 17 feet. In columns, again, every architect must confess, that the proportion of height and thickness varies betwixt eight diameters and ten, and that every proportion between these two extremes is agreeable. Besides there must certainly be a further variation of proportion, depending upon the size of the column. A row of columns ten feet high, and a row twice that height, require different proportions; the inter-columniations must also differ in proportion according to the height of the row.

Proportion of parts is not only itself a beauty, but is inseparably connected with a beauty of the highest relish, that of concord and harmony; which will be plain from what follows. A room, the parts of which are all finely adjusted to each other, strikes us not only with the beauty of proportion, but with a pleasure far superior; the length, the breadth, the height, raise each of them a separate emotion. These emotions are similar; and though faint when separately felt, they produce in conjunction, the emotion of concord or harmony, which never fails to please. On the other hand, where the length of a room far exceeds the breadth, the mind, comparing together parts so intimately connected, immediately perceives a disagreement or disproportion which offends. Hence a long gallery, however convenient for exercise, is not an agreeable figure for a room. In buildings destined chiefly or solely to please the eye, regularity and proportion are essentially necessary, because they are the means of producing beauty. But a skillful artist will not confine his view to regularity and proportion; he will also study congruity, which is perceived when the form and ornaments of a structure, are suited to the purpose for which it is appointed. Hence every building ought to have an expression suited to its destination. A palace, ought to be sumptuous and grand; a private dwelling, neat and modest; a play-house, gay and splendid; and a monument, gloomy and melancholy. Columns, besides their chief destination of being supports, contribute to that peculiar expression which the destination of a building requires. Columns of different proportions serve to express loftiness, lightness, &c. as well as strength. Situation may also contribute to expression; conveniency regulates the situation of a private dwelling-house; and the situation of a palace ought to be lofty. The external structure of a house, leads naturally to its internal structure. A large and spacious room, which is the first that commonly receives us, is a bad contrivance in several respects. A more agreeable arrangement is a handsome portico, proportioned to the size and fashion of the front, leading into a waiting-room of a larger size, and this to the great room, all by a progression from small to great.

The several offices, which have a place in the plans of houses, should be so arranged, as to appear to compose an inferior part of the whole building; not totally detached, yet in such order as to keep the more offensive ones as remote as possible from the principal parts of the house.

It has been doubted whether a building can admit of any ornaments beyond such as are useful, or at least that have the appearance of being so. But, regarding architecture no less as a fine, than as a useful art, both kinds may be introduced; though it requires great

great judgment as to the quantity and the arrangement. A private house, and other edifices, where use is the chief aim, admit not indeed of any ornaments but such as have the appearance of utility. But temples, triumphal arches, and such buildings as are chiefly intended for show, may be highly ornamented without any regard to their seeming usefulness. Hence it is that a threefold division of ornaments has been suggested. These are, first, ornaments that are beautiful without relation to use; such as statues, vases, &c. Secondly, objects in themselves not beautiful, but possessing the beauty of utility, by imposing on the spectator, and appearing to be useful; such as blind windows. Thirdly, where things are beautiful in themselves, and at the same time assume the appearance of use; such as pilasters. With regard to the first, we naturally require that a statue shall be so placed as that it may be seen in every direction, and at various distances, by having an opportunity of receding or advancing as we please; statues placed in the niches in fronts of houses, or on the tops of their walls and roofs, ought not to be admitted. Their proper places are in large halls, and in passages that lead to a grand stair-case, &c. To adorn the top of a wall with a row of vases, is an unhappy conceit; by placing a thing, whose natural destination is utility, where it cannot have even the least appearance of it. Firmness and solidity being the proper expressions of a pedestal, whether of a column, or of a statue, it ought to be sparingly ornamented. The ancients never ventured on any bolder ornament than the basso relievo.

With respect to ornaments of the second kind, it is a great error to contrive them so as to appear useless. A blind window, therefore, when necessary for regularity, ought to be so disguised as to appear a real window; when it appears without disguise, it is disgustful, as a vain attempt to supply the want of invention; it shews the irregularity in a stronger light, by signifying that a window ought to be there in point of regularity, but that the architect had not skill sufficient to connect external regularity, with internal convenience. As to the third; it is very injudicious to sink pilasters so far into the wall, as to remove totally, or mostly, the appearance of use. They should always project so much from the wall, as to have the appearance of supporting the entablature over them.

Of all ornaments the pillar gives the greatest elegance to extensive buildings. The destination of a pillar is to support, really, or in appearance, another part, termed the entablature. With regard to the form of a pillar, it must be observed, that a circle is a more agreeable figure than a square; a globe than a cube; and a cylinder then a parallelopipedon. This last, in the language of architecture, is saying, that a column is a more agreeable figure than a pilaster; and for that reason it ought to be preferred, when all other circumstances are equal. Another reason concurs, that a column annexed to a wall, which is a plain surface, makes a greater variety than a pilaster. Besides, pilasters at a distance are apt to be mistaken for pillars; and the spectator is disappointed, when, on a nearer approach, he discovers them to be only pilasters.—Ornaments intended to decorate the orders, should be judiciously adapted to the proper character of each. Plain and rusticated embellishments would be extremely discordant with the elegance of the Corinthian column; and sweet and delicate enrichments very ill suit the strength and simplicity of the Doric. All kinds of fanciful and trifling devices, all fashionable finery, should be for ever excluded from the smallest place in our works. Sir Christopher Wren, very justly censures this species of frivolity, when speaking of the palace of Versailles. Much to the honour of Sir William Chambers, architect of that great national ornament Somerset-house, he has never depraved the art with any kind of capricious innovation. He has ever made the ancients his models; and he has not pretended to vary and invent, where variation and invention are not only superfluous, but mischievous. He has only, with great taste and judgement, selected and compounded what he has already found perfect to his hands. His buildings are consequently always grand, yet simple; not distracting the eye with broken lines, petty divisions, or arbitrary and meretricious ornaments; but preserving always that unity of design, and that magic of effect, which render them the best comments on his own excellent treatise on the Science of Architecture.

We shall now give some rules for working the orders of Architecture. An order consists of three principal members, or parts: which are, the pedestal, the column, and the entablature. Each of these parts is again composed of three others; the pedestal, having its base, its die or trunk, and its cornice. The column has its base, its shaft, and its capital. And the entablature consists of the architrave, frieze, and cornice. A competent knowledge of the methods of drawing and working the five orders, may be said to be the very foundation of the art of building; since from these, with their several proportions and ornaments, arises all that is great, elegant, or harmonious, in the noblest structure. It should, therefore, be the earnest endeavour of those who study architecture, to obtain a thorough knowledge of each distinct order, its parts, proportions, and genuine figure, as being absolutely necessary to every one who aspires to eminence in this profession. The following rules are given with this view, and are adapted to the present taste; and they are so clearly explained by the figures and measurements on the plates, that a little attention will enable every person readily to compehend the proportion, use, and situation of each member; and also the several methods adopted in calculating the parts, and setting them off for practice. As architecture is more the study of forms than precepts,

precepts, we regret that the limits of the present work, do not enable us to give many plates of examples from antiquity, which would tend much to confirm what has already been said. We therefore recommend to the attention of those who may wish to know more of this subject, the following excellent works:—Nicholson's Principles of Architecture; Stuarts' Athens, and Sir Wm. Chambers' Treatise on Civil Architecture.

Of diminishing the Shaft of a Column. In effecting the diminution of the shaft of a column, the ancients adopted a variety of methods; beginning sometimes from the foot of a shaft, and at others from one quarter, or one third of its height, the lower part being perfectly cylindrical. The former of these was most in use among the ancients, and, being the most natural and graceful ought to have the preference, though the latter has been more universally practised by modern artists. The first architects, says M. Auzoult, probably made their columns in straight lines, in imitation of trees, so that their shaft was the frustrum of a cone; but, finding this form abrupt and disagreeble, they made use of some curve, which, springing from the extremities of the superior and inferior diameters of the column, swelled beyond the sides of the cone, and by that means gave a more pleasing figure to the contour. Vitruvius, in the second chapter of his third book, mentions this practice, but in so obscure and cursory a manner, that his meaning has not been understood; and several of the modern architects intending to conform themselves to his doctrine, have made the diameters of their columns greater in the middle than at the foot of the shaft. Leon Baptista, Alberti, and others of the Florentine and Roman architects, have carried this to a very great excess, for which they have been justly blamed, as it is neither natural, reasonable, nor beautiful. M. Auzoult observes, that a column supposing its shaft to be the frustrum of a cone, may have an additional thickness in the middle, without being swelled there, beyond the bulk of its inferior parts; and supposes the addition mentioned by Vitruvius, to signify nothing but the increase towards the middle of the column, occasioned by changing the straight line, which at first was in use for a curve. This supposition is extremely just, being founded on what is observed in the works of antiquity; where there is no instance of columns thicker in the middle than at the bottom, though all have the swelling hinted at by Vitruvius, all of them being terminated by curves, some granite columns excepted, which are bounded by straight lines; a proof, perhaps, of their great antiquity. M. Blondel teaches various methods of diminishing columns, the best of which is by means of that instrument, which Nicomedes invented to describe the first conchoid, for this, being applied at the bottom of the shaft, performs at one sweep both the swelling and the diminution; giving such a graceful form to the column, that it is generally allowed to be the most perfect practice hitherto discovered. The columns in the Pantheon, accounted the most beautiful among the antiques, are made in this manner; as appears by the exact measures of one of them to be found in Desgodetz's Antiquities of Rome. To have an accurate idea of the operation, it will be necessary first to describe Vignola's method of diminution, on which it is grounded. Having described the height of the shaft, and its inferior and superior diameters, draw a line indefinitely from C through D perpendicular to the axis of the column, (*See Plate* 1, *Figure* 1.) this done, set off the distance C D, which is the inferior semi-diameter from A, the extreme point of the superior diameter to B, a point in the axis. Then from A through B, draw the line A B E, which will cut the indefinite line C D in E; and from this point of intersection E, draw through the axis of the column any number of rays, as E B A; on each of which, from the axis towards the circumference, setting off the interval C D, may be found any number of points, as *a a a*, &c. through which, if a curve be drawn, it will describe the swelling and diminution of a column.

Though this method be sufficiently accurate for practice, especially if a considerable number of points be found, yet strictly speaking, it is defective, as the curve must either be drawn by hand, or by applying a flexible ruler to all the points; both of which are liable to variations. Blondel, therefore to obviate this objection, after having proved the curve passing from A to C, through the points *a a a* &c. to be of the nature of the first conchoid of the ancients, employed the instrument of Nicomedes to describe it, the construction of which is as follows; having found the length of the shaft, with the inferior and superior diameters of the column, and the length of the line C D E, *(in architecture plate as before,)* take three rulers either of wood or of metal, as F G, I D, and A H of which let F G and I D, be fastened together at right angles in G. Cut a dove-tail groove in the middle of F G, from top to bottom, and at the point E, on the ruler I D, (whose distance from the middle of the grove in F G, is the same as that of the point of intersection from the axis of the column,) fix a pin; then on the ruler A H set off the distance A B equal to C D, the inferior semi-diameter of the column, and at the point B fix a button, whose head must be exactly fitted to the groove made in F G, in which it is to slide; and at the other extremity of the ruler A H, cut a slit or channel from H to K, whose length must not be less than the difference of length between E B and E D, and whose breadth must be sufficient to admit the pin fixed at E, which must pass through the slit, that the ruler may slide thereon. The instrument being thus compleated, if the middle of the groove in the ruler F G, be placed exactly over the axis of the column, it is evident that the ruler A H, in moving along the groove, will, with its extremity A, discribe the curve A *a a* C; which curve is the same as

that produced by Vignola's method of diminution, supposing it done with the utmost accuracy for the interval A B, *a b*, is always the same; and the point E is the origin of an infinity of lines, of which the parts B A, *b a*, *b a*, extending from the axis to the circumference, are equal to each other, and to D C. And if the rulers be of an indefinite size, and the pins at E and B be made to move along their respective ruler, so that the intervals A B and D E may be augmented or diminished at pleasure, it is likewise evident, that the same instrument may be thus applied to columns of any size. With regard to the generally received opinion, that, in proportion as columns are elevated, the eye is deceived in the contour, and, therefore, they require a difference in the diminution to allow for this effect, it seems proved by Perrault to be on most occasions a mistake. If we judge by the rigour of optical laws, it must be remembered, that the proper point of view for a column of fifty feet high, is not the same as for one of fifteen, but on the contrary, more distant, in the same proportion as the column is higher; and that consequently, the apparent relation between the lower and upper diameters of the column will be the same, whatever be its size. For, if we suppose A *figure* 2. *Plate* 1, to be a point of view, whose respective distance from each of the columns *f g*, F G, is equal to the respective heights of each, the triangles *f* A *g*, F A G, will be similar; and A *f*, or A *h*, which is the same, will be to A G as A F, or its equal A H is to A G; therefore if *d e* be in reality to *b c*, as D E, is to B C, it will likewise be apparently so; for the angle *d* A *c*, will then be to the angle *b* A *c*, as the angle D A E, is to the angle B A C; and if the real relations differ, the apparent ones will likewise differ. In this figure, the eye of the spectator at A, is supposed to be in a line perpendicular to the foot of the shaft; but, if the columns be proportionably raised to any height above the eye, the argument will still remain in force, as the point of view must of course be proportionally more distant; and even when columns are placed immediately on the ground, which seldom or ever is the case, the alteration occasioned by that situation is too trifling to deserve notice. When, therefore, a certain degree of diminution, which, by experience, is found pleasing, has been fixed upon, there will be no necessity for changing it, whatever be the height of the column; provided the point of view is not limited. But in close places, where the spectator is not at liberty to choose a proper distance for his point of sight, the architect, if he inclines to be scrupulously accurate, may vary; though it is in reality a matter of no importance, as the nearness of the object, will render the image thereof, indistinct, and consequently, any small variation will be imperceptible.

By the following method also, columns may be diminished with great ease and facility, only by the help of a common measuring rule, which every workman may make. Describe a semi-circle, on the bottom of the column A B, as shewn at *Figure* 4, *Plate* 1; from the top of the column draw the line E 4, parellel to the axis, D C, or middle line of the column, cutting the semi-circle at the base in 4; divide the arch B 4, into 4, or any other number of equal parts, and divide the height, C D, into the same number of equal parts; as, 1, 2, 3, through the divisions 1, 2, 3, 4, of the semi-circle, at the base, draw lines 1 *a*, 2 *b*, 3*c*, and 4 *d*, parallel to, A B; set off these parts from each side of the axis, on the corresponding numbers of the shaft; then, by bending a thin lath or slip round pins or nails fixed in those points, it will give the contour, or curve of the column; and the reverse of this will be the edge of the diminishing rule for working it by. Or, divide the height of the diminishing rule B E, into any number of equal parts, as four, at *a*, *b*, *c*, and divide the difference of the semi-diameter at the top and bottom, into the same number, viz.—four, and draw lines from each division parallel to the base, through 1, 2, 3, which points will produce a curve of a very regular and pleasing form, that may be drawn on the edge of the rule, or on the column itself, as is most convenient for the workmen.

Mouldings.—1st. Mouldings are figures composed of various curves and straight lines. If they are only composed of parts of a circle, they are called Roman, because the Romans, in their buildings, seldom, or never employed any other curve for mouldings than that of a circle; but if they are made of part of an ellipsis, or a parabole, or an hyperbole, the mouldings are then in the Grecian taste. Hence, mouldings in the Greek taste, are of a much greater variety then those of the Roman, where only parts of circles are concerned; and they have various names, according to the manner in which they are curved.

2d. The straight lined part under or above a moulding, in general is called a fillet.

3d. If the contour of a moulding be convex, and a part of a circle equal to, or less than a quadrant, then the moulding is called a Roman ovolo, or echimes.

4th If the contour of the moulding be concave, and equal to or less than a quadrant, it is called a cavetto, or hollow, so that a cavetto is exac the reverse of an ovolo.

5th A bead is a moulding, whose contour is simply a convex semi-circle.

6th. If the contour be convex, and a complete semi-circle, or a semi-ellipsis, having a fillet above or below it, the moulding is called a torus. Thus, a torus is a bead with a fillet, and is more particularly distinguished in an assemblage of mouldings from a bead, by its convex part being much greater.

7th. If the contour of a moulding be a concave semi-ellipsis, it is called a scotia.

8th. If the contour be convex, and not made of any

any part of a circle, but of some other of the conic sections, having a small bending inwards towards the top, the moulding is called a Grecian ovolo, or echinus.

9th. If the contour be partly concave, and partly convex, the moulding in general is called a cimatium.

10th. If the concave parts of the curve project beyond the convex parts, the cimatium is called a cima recta.

11th. If the convex part project beyond the concave, the cimatium is called a cimakecta, or ogee.

12th. The bending, or turning inwards, of a small part of the convex curve of a Grecian moulding, is, by workmen, called a quirk.

PLATE II.

To describe the torus. *Figure* 1.—Divide the height into two, equal at *e*, and on *e*, as a centre, describe a semi-circle to that height, and it will form a torus. The bead *Figure* 2, is formed as the torus.

To describe an ovolo. *Figure* 3.—Take the height *a b*, set the compasses in *b*, describe an arc, and with the same distance, on the projection at *c*, describe an arc cutting the former at *a*, then on *a*, as a centre, describe an arc, *b c*, and the ovolo will be completed.

To describe a caveto. *Figure* 4.—On *b*, with the height *a b*, describe an arc on the projection at *c*, with the same distance describe another arc, cutting the former at *d*; then with the same extension on *d*, describe the arc *b c*, and it will be a cavetto.

To describe a cimarecta. *Figure* 5.—Join the projections at each end by the right line, A B, divide it into two equal parts, at *h*, and in order to make it look bold, divide A B into three equal parts, or nearly so, and with one third, on A and *h*, as centres, describe arcs, cutting each other at *d*; and in the same manner, find the intersection, on the opposite side of the line at *c*; lastly on *d*, and *c*, describe the arcs A *h*, and *h* B, and it will form the cimarecta required. These are the forms of regular mouldings, viz.—the height, equal to the projection; but there are other forms, where the projection is often less than the height, and the curvature of the moulding much flatter; however the same methods for describing the one, will do for the other.

MODERN, OR QUIRKED MOULDINGS.

To describe the cima reversa. *Figure* 6.—join the projections at *a*, and *b*, by the line *a b*, and proceed in the same manner as with the cima recta, before described.

To describe a quirked cima reversa. *Figure* 7.—Divide the perpendicular height into seven parts; with two of the parts describe a semi-circle, *c e*, on *a* draw a line from *e c*, and on the height of the first division, from the bottom *b*, describe the arc *c d*, and it will complete the moulding.

To describe a quirked ovolo. *Figure* 8.—Divide the height into four equal parts, with one part on *c*, describe the arc *a f g*. Join *c b*, to the fillet below; on *b*, describe the arc *c d* on *c*, with the distance *a b*, describe an arc cutting the former at *d*; through *d* and *c*, draw the line *d c f*, cutting the small circle at *f*, then with a radius *d f*, describe the arc *f b*, and it will complete a quirked ovolo.

To describe the quirked moulding, *Figure* 9, flatter in the lower part than that at *Figure* 8.—Describe the smaller circle as in the last, and through its centre, and the end *b*, of the fillet, draw the line *e b c*, taking the point *e*, according as you intend to have the under part of the moulding, flatter or quicker; take the distance *e c*, and on *b*, describe an arc at *d*, then take the distance *e a*, that is *e c*, made less by the radius *c a*, of the smaller arc *a f g*, on *c*, with that distance, describe an arc, cutting the former at *d*; lastly on *d*, with a radius *d f*, describe the arc *f b*, and it will complete the quirked ovolo required.

These are the most proper for the workman's purpose, though various other methods may be shewn to answer the same purpose; 10, 11, 12, 13 14, which are traced from a semi-circle, by applying the same projections to a line of any inclination required. 10 is a torus moulding taken from a semi-circle; and may be applied where the projection of the upper fillet is greater than the projection of the lower.

To describe a scotia. *Figure* 15.—From the top of the fillet draw B A, perpendicular, cutting the bottom of the fillet at A; from *g*, the end of the bottom fillet; draw the line *g a c*, parallel to A B; make *g a*, equal to twice *g* A, on A; describe the semi-circle *g e c*, cutting the line *g a c*, at *c*, through *c*, and the end of the fillet, at B, draw the line *c* B *e* cutting the semi-circle at *e*; draw the line *a d e*, cutting A B, in *d*; lastly on *d*, describe the arc *e* B and it will complete the scotia.

16 is a scotia, described by a similar method to the ovolo's 10, 11, 12, 13, 14, viz. through points found from a semi-circle, to the height of the moulding.

To describe a Grecian ovolo or echines.—Have two tangents to the curve, and the points of contact given, one of the points of contact being the greatest projection, and the other being the lower extremity of the curve.

Figures 17 and 18,—let A B, B C, be the two tangents, A the point of contact at the greatest projection, and C, the lower extremity of the curve; draw A E, parallel to B C, and C E, parallel to B A; produce C E, to F, making E F, equal to E C; divide A E, and A B, each into the same number of equal parts; from the point F, draw lines through the points of division in A E, and also from the point C, draw lines to the points of division in A B, to meet the others through the divisions of A E; through the intersections, draw a curve, which will be the contour of the ovolo required.

The

The moulding will be flatter or quicker, according as the point B, the extremity of the tangent B C, is nearer or more remote from A, the greatest projection.

Figure 19.—Draw A H, parallel to the fillets; produce the vertical line C H, to K, making H K, equal H C, and H I, equal to B D; join A I; divide A I, and A B, each into the same number of equal parts, and through the points of division in these lines, and through the points K and C, draw lines to meet each other, and through these points draw a curve, and it will be the ovolo required.

If B D, were less than the half of A D, the moulding would be elliptical, and if B D, were equal to the half of A D, the moulding would be parabolical. In this example B D, is greater than the half of A D, the moulding is hyperbolical. Of this form is the echinus in all the Grecian Doric capitals, except the Doric portico at Athens, in which the echinus of the capital is elliptical.

Figure 21, is a scotia or tochilus, the fillets may be considered as tangents, and the line parallel to the line joining the fillet as another tangent.

Figure 22, a cimarecta, compounded of two quarters of an ellipse upon the axis, *Figure* 23, a cimareversa compounded of two quarters of an ellipse, from conjugate diameters, which are given in position. These are described upon similar principles to *Figures* 17 and 18.

Figure 20. To describe a hollow to touch with two straight lines B, D and B, A, one of them at a given point A.—Let D, be the point of their meeting, make D B, on the other line equal to D A; from the points A and B, draw perpendiculars to each of the lines D B, and D A, meeting at C: on C, as a centre with the radius C B, or C A, describe an arc B A, and it is done.

TO DRAW THE FLUTES OF THE COLUMNS,

To draw the flutes of the Doric columns.—On A B, *Figure* 5,—*Plate* 1. the diameter of the column, describe a semi-circle, and divide the semi-circle into two equal parts; (as the Doric column usually contains twenty flutes, which are in general made shallow, and without fillets); through every two of the divisions draw lines E 1, E 2, E 3, E 4, to E 10, between any two divisions, (as 3 and 4), describe two arcs, whose vertex is C; on E with a radius E C, describe the quadrant G, H, I, K, L, M, cutting the lines E A, E I, E 2, E 3, E 4, &c. in the points G, H, I, K, L, M, which are the centres for the flutes; but if the flutes are wanted deeper, you may make the distance 5 D, half the breadth of a flute, and proceed as shown on the other quadrant, and from *a*, *b*, *c* &c. draw perpendiculars to the bottom of the column.

The Ionic Corinthian, and Composite orders, have in general twenty four flutes, with a fillet between each; (the fillet one third of a flute,) in order to have that number, and preserve the just proportion of a flute to a fillet, observe the following rule; divide the semi-circumference. (*Plate* 1. *Figure* 7.) into twelve equal parts, at 1, 2, 3, &c to 12, divide any division into eight equal parts, as that between five and six, then take three of these parts, and on 1, 2, 3, &c to 12, as centres; describe arcs which are nearly semi-circular as in the plate, and then draw them to the column.

TO DRAW THE FLUTES AND FILLETS ROUND THE SHAFT OF A COLUMN.

If the columns are of stone, or wood, the whole or any part may be fluted in the following manner; after being properly rounded, and the ends or joints made parallel to each other, find the centres of the circles at each end; and if they are not already found, cut two holes, directly in the middle at each end, perpendicular to the joints, so that the centers shall be in the middle of the holes; this being done drive in two pieces of wood, so as to be quite tight in the holes, and to project out about five or six inches; let the projecting parts be well rounded off, so as to be exactly in the middle of the ends; then make a diminishing rule, as in *Plate* 1. *Figure* 3. To fit the curve of the column, let t e ends of this diminishing rule be fixed into two pieces *a b*, which are made to revolve round the pins at the ends, by means of notches, or any other convenient way, so that the curved edge of the rule, be very near to the curved surface of the column; and one side of the rule to tend exactly to the centre. To keep the rule steady from bending sideways, fix a rule to the other side, the whole length of the diminishing rule, of a sufficient strength to keep the diminishing rule from bending;, so that the breadths of the two rules will be at right angles to each other, the two end pieces and diminishing rule being fixed fast together, the whole may be turned round the pins at the ends as centres, like one entire piece; then the operation of drawing the flutes and fillets will be as follows;—suppose it were required to flute the Ionic, Corinthian, or Composite columns, the circumference at either end will be divided into six equal parts, by taking half the diameter at that end, and applying it round the said circumference; then each of these divisions being divided into four, the whole circumference will be divided into twenty-four; in order to have the proportion of a flute to a fillet, as 1, to 3, divide any one of the last divisions into four equal parts, and one of these parts will be the breadth of a fillet; which being set off from the same side of each division, the whole column will be divided into flutes and fillets; then by turning the rule round to each mark, or division, you may make a piece of sharp steel draw on the shaft of the column, the flutes, and fillets, to the greatest exactness, by keeping it close to the side of the rule.

This method is by far the most ready, as well as the most correct of any that we have yet seen; this machine is shewn complete on the plate, and we hope a careful inspection will render it sufficiently plain.

plain; there are other methods of drawing the flutes on the shaft of a column, as by drawing two parallel lines through the centre, at each end of the column, and dividing the circumferences at the ends, into a number of flutes and fillets, then bending a thin rule from the respective divisions at each end. It is necessary to be careful, that the edge of the rule by which you draw, touch the curved surface of the column only; but, this method however, simple, is very liable to error. The methods that some workmen make use of, for setting off the flutes and fillets round the shaft of a column, are as follow:—

To draw the flutes and fillets on a column or pilaster.—*Plate* 1. *Figure* 9.—A B, is any line divided into flutes and fillets, greater than the circumference at the base; on A B, describe the equilateral triangle A B G, draw all the points in A B, to G; then if G C, and G D, are equal to the circumference of the column at the bottom of the shaft, the line C D, will be equal to the same circumference; lay a piece of parchment, or any thing that is pliable, on C D, and mark all the flutes and fillets on it, then apply this round the column at the bottom, and prick them round it, divide the circumference at top, in the same manner as E E, and draw the flutes with a thin rule, as before.

Plate 1. *Figure* 10—is another method for marking the flutes and fillets round the ends of the column; the line A B, is a line divided into flutes and fillets, less than the circumference of the top part of the column; draw any number of parallel lines, from the divisions of A B, let B C, B D, B E, be at the top or bottom diameter: set one foot of the compasses in B, and cross the line A F, at C D, or E, draw the line B C, B D, or B E, and either will be divided into flutes and fillets, as before.

Plate 1. *Figure* 11.—Let A B, be the breadth of the pilaster, draw any line A C, take your compasses at any convenient opening, and run twenty-nine times the said opening, from A, to C, and join B C, then set your level to the angle A C B, and from the points on A C, draw lines cutting A B, as is shewn by the figure, and from the points on A B, draw the flutes and fillets with a common guage.

There is another method of drawing the flutes of a diminished pilaster, with one guage, and at one movement, by making the guage equal to the width of the bottom, or something wider; but as this method is erroneous in its principle, no diagram is exhibited.

The best method to draw the flutes on a diminished pilaster; is to divide the height of the trunk into any convenient number of equal parts, on a longitudinal line, passing through the middle of the breadth at top and bottom, and through the points of division, draw transverse lines to the longitudinal line; set off the flutes and fillets on each transverse line; take nails or brads in each corresponding point of each transverse line, and bend a pliable slip of wood round the nails, and draw a line, and proceed till every set of corresponding points are used, and the pilaster will have its face drawn for the flutes.

To describe the Ionic Volute, Plate 3, *Fig.* 4.—Divide the height P Q, into 7 parts, upon the third division describe a circle about C, as a centre, whose diameter will be equal to one of the parts; draw V W, X, U, and in that square draw another, whose angles shall touch the sides of the former square in the middle. In order to make the construction of the centres appear plain, the centre part is shown above, of a larger size, and the same letters of reference put to each; divide C 1, and C 2, each into three equal parts, at 9, 5, 10 and 6, divide C, 10, into two equal parts at x, if the volute is intended to be at the right hand, as in this example; but if on the left, divide C 9, into two equal parts, and proceed in each case as follows; from x draw the perpendicular line, cutting the side S F, of the square at D; from D, make D E, and D F, equal to G 1, or G 2,; join E H and F H, draw 5 4, 9 8, 10 11, and 6 7, parallel to the perpendicular side of the square, cutting E H, and F H, at 4, 8, 3, 7, 11; then 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12, are the centres. Begin at 1, and with the radius 1 A, describe the quadrant A B, of the volute; on 2, with the radius 2 B, describe the quadrant B C; on 3 describe the quadrant C D; proceed in this manner with all the quadrants, till you touch the eye at U, and it will complete one side of the fillet.

To draw the inside of the fillet.—Divide the thickness of the list A a, at the top, into twelve equal parts by means of the scale N O R, as follows;—begin at N, and with any opening of the compass run it twelve times from N, to O; draw O R, making any angle with O N; make O R, equal the thickness of the fillet at A a; join R N, draw a 11, b 10, c 9, d 8, &c. parallel to R O, make the thickness of the list B b, equal to a 11; and D d equal to b 10, &c. at the beginning of every quadrant; join a b, and bisect it by a perpendicular, meeting the eye a little within the first centre, set the small distance within all the other centres, and proceed to describe the inside of the list, in the same manner as the outside, and it will end in a point with the outside at U, and the volute will be completed.

To draw an angular volute.—Divide the perpendicular height A B, as in *Plate* 3. *Figure* 5. into twenty-three equal parts; take the centre G, ten divisions from the bottom, or thirteen from the top, through the centre G, draw H I, perpendicular to A B; bisect the angle B 10 I by the diagonal line D C; through the first division O above H, on the line A B, draw O E parallel to H I, cutting the line D C at E, on G as a centre, with a radius G E, describe a circle cutting D C on the opposite side of the centre at F; divide F E into six equal parts at 3, 5, G, 6, 4 F, then on E as a centre with a radius E P describe an arc P C cutting D C at C on F with a

radius P C describe the semicircle C I K, cutting C D at K, on 3 with a distance 3 K describe a semi-circle K L on 4 as a centre with the radius 4 L describe a semi-circle L M, on 5 as a centre, with a radius 5 M, describe a semi-circle M N: lastly on 6, with a radius 6 N, describe a semi-circle N E, touching the centre at E, then figure 1 will be completed. This method will describe an elliptical volute, to a given height, but not to any given width, this is only a preparation to what follows.

To describe an elliptical volute, to any given height and projection from the centre.—Divide the given height L M, *Plate* 3. *Figure* 6. into twenty-three equal parts as before, taking the centre E, ten from the bottom, or thirteen from the top, through N, the first division above E, draw N F, cutting the diagonal line E O, at F, on E as a centre, with a radius E F, describe the dotted circle, or through E, draw P Q, at right angles to the diagonal line O S, make E P and E Q, each equal E F, on F, as a centre, with the distance L F, describe an arc L H, cutting E H at right angles to L M at H, from E, make E G, equal to the distance the projection of the volute is intended to be from the centre, divide G H into six equal parts, and set one of the parts to I, make E K, and E R, each equal to the sum of the two lines E F, and G I, through the points K, P, R, Q, complete the parallelogram A, B, C, D, whose sides A B, D C, are parallel to P Q and A D, B C, parallel to K R, draw the diagonals A C and B D, and divide each of them into six equal parts, then on B as a centre, with the radius B L, describe the arc L *b*, cutting A B, produced at *b*, on A as a centre, with the radius A *b*, describe the arc *b c*, cutting A D, produced at *c*, on D, as centre with the radius D *c*, describe an arc *c d*, cutting C D, produced at *d*, on C, as a centre, with a radius C *d*, describe an arc *d e*, on 5, as a centre, with a radius 5 *e*, describe an arc *e f*, on 6 as a centre with the radius 6 *f*, describe an arc *f g*, on 7 as a centre, with the radius 7 *g*, describe an arc *g h* on 8 as a centre, with the radius 8 *h*, describe an arc *h i*, proceed in this manner, beginning the third revolution at 9, till you end at 12; lastly describe an ellipsis touching the last centre of the third revolution E, being its centre, and its transverse and conjugate axis being in the same ratio as the length or height of the volute is to its width, and it will be finished.

Directions for drawing the Tuscan or any other order.—

A.	Fillet	MOULDING IN THE CORNICE
B.	Cima recta	
C.	Fillet	
D.	Corona	
E.	Ovolo	
F.	Fillet	
G.	Cavetto	
H.		FRIEZE
I.	Tenia	ARCHITRAVE.
K.	Upper Fascia	
L.	Lower Fascia	
M.	Abacus	CAPITAL
N.	Ovolo	
O.	Fillet	
P.	Neck of the Capital	
Q.	Bead	ASTRAGAL
R.	Fillet	
S.	Fillet	BASE.
T.	Torus	
V.	Plinth	

In the instances which we have chosen of the five orders, the height and projection of the mouldings are marked in minutes, for finding which, a rule is hereafter subjoined.

Divide the diameter of the column at the bottom, into two equal parts, called modules, divide each of these into thirty, which are called minutes; then every member of the order is so many minutes of this scale, either in height or projection; the operation is as follows; draw an axis or perpendicular, through the middle of the column; on this line set all your heights, or on any other line parallel to it; then make another line parallel to the axis, at the distance of twenty-five minutes, which allows five minutes on each side, for the diminution at top; from this line set off your projections, as figured at *Plate* 4 *Architecture*, for example, the projection of the top fillet A, is 66 minutes, and the projection of the next fillet C is 54 minutes and a quarter; then proceed to draw the cima-recta, as already shewn at *Plate* 2. *Figure* 5. and afterwards all the other members.

In the Tuscan order, the column is seven diameters high, that is, seven times its diameter at the base, the entablature is one-fourth of the height of the column; but if the order has a pedestal, which is seldom the case, it will be one-fifth part of the entire order in height. To make this practice obvious to the reader, the following examples will be useful;—

To find the diameter of the Tuscan column, when that alone is to be executed.—RULE. Divide the height of the column by seven, and the quotient will be the diameter.

Example 1.—Suppose it were required to execute the Tuscan column alone, to the height of 22 feet three inches; demanded the diameter of the column.

$$7\,)\,22\,..\,3$$
$$\overline{\;3\,..\,2\tfrac{1}{7}\;}$$

So that the diameter of the column is three feet two inches and one-seventh part of an inch.

To find the height of the Tuscan entablature, and the

the diameter of its column, the entire height of the column and entablature being given.—Rule. Divide the height by five, and the quotient will give the height of the entablature last found from the entire height, and the remainder will be the height of the column; divide this remainder by seven, as before, and the last quotient will be the diameter of the column.

Example 2.—Suppose it were required to execute the Tuscan with its entablature, to the height of twenty-two feet one inch; demanded the height of the entablature, and the diameter of its column.

5) 22 .. 1

4 .. 5 height of the entablature

7) 17 .. 8 height of the column

2 .. $6\frac{2}{7}$ diameter of the column.

The diameter of the column being thus found, it will easily be put in, as follows; suppose it were required to execute a column to two feet six inches and two-seventh parts of an inch; take a rod of that dimension, and divide it into six equal parts, and the first part again into ten, for minutes, then proceed for practice in the same manner as if the drawing were to be on paper.

To find the diameter of the column, the height of the entablature, and height of the pedestal, when the whole is to be executed to a given height.—Rule. Divide the entire height by five, and the quotient will be the height of the pedestal; subtract this height from the entire height, and the remainder will be the height of the column, with its entablature. Divide the remainder again by five, and the quotient will be the height of the entablature; subtract the quotient from the first remainder, and the last remainder will be the height of the column; and this last remainder, being divided by seven, will give the diameter of the column.

Example 3.—Let it be required to execute the Tuscan order complete, with an entablature, column, and pedestal, to the height of thirty feet; demanded the height of the pedestal, height of the entablature, and diameter of the column?

5) 30

6 feet, the height of the pedestal.

5) 24 height of the column and entablature.

4 .. $9\frac{3}{5}$ height of the entablature

7) 19 .. $2\frac{2}{5}$ height of the column.

2 .. 8^5 diameter of the column.

To draw the Tuscan column to a given height.—Divide the height into seven equal parts, as in the second example; one will be the diameter of the column, and a scale whereby to proportion the other parts.

To draw the Tuscan column, with its entablature, to a given height.—Divide the given height into five equal parts; allow one for the height of the entablature; and then divide the remaining four into seven parts, of which one will be the diameter of the column.

To draw the Tuscan column and entablature, standing upon a sub-plinth.—Divide the whole height, into twelve equal parts, one will be the height of the sub-plinth; divide the remaining eleven into five equal parts, one will be the height of the entablature; divide the remaining four parts into seven, and one will be the diameter of the column.

To draw the Tuscan order entire with a pedestal.—Divide the whole height into five equal parts, the lower one will give the height of the pedestal; divide the remaining four into five equal parts, the upper one will give the height of the entablature; divide the remaining four of these into seven equal parts, and one is the diameter of the column.

The manner of setting off the parts of the Doric order, is much the same as in the Tuscan; the heights and projection of the parts being taken from the diameter of the column at bottom, forms a scale for each of the orders; so that the drawing and executing of the Tuscan, if well understood, teaches to draw the Doric, or any other order, without further instruction or repetition. The greatest difficulty of the Doric order are the triglyphs; these, in modern buildings, are placed exactly over the centre of the column, thirty minutes wide, so that fifteen minutes are on each side of the axis of the column; the mutules in the cornice are exactly over them, and of the same breadth; the small conical frustrum under the triglyphs are called drops, or bells; the manner of drawing the triglyphs and bells is as follows: divide the breadth into twelve equal parts, give one to each half channel on the outside; two for each space or interval, and two for each channel, and one space will remain in the middle; every two divisions or parts is the width of a bell; the side of every bell, if continued, would terminate in a point at the top of the fillet above them; the spaces between the triglyphs, called metopes, are always square, and sometimes enriched with ox-heads, and sometimes with pateras, according to fancy; when the column is fluted it has twenty in number, and without fillets.

TO PROJECT THE DORIC ORDER TO A GIVEN HEIGHT.

For the column.—Divide the height into eight equal parts, one of the parts is the diameter of the column, which diameter is to be divided into sixty.

sixty minutes, as has been before directed, for practice.

For the column and entablature.—Divide the given height into five equal parts, and the upper part will give the height of the entablature; divide the remaining four into eight equal parts, and one will give the diameter of the column.

For the column and entablature upon a sub-plinth.—Divide the given height into twelve equal parts, the lower one will give the height of the sub-plinth, divide the remaining eleven into five equal parts, the upper one is the height of the entablature; divide the remaining four parts into eight, and one of these is the diameter of the column.

For the column and entablature upon a pedestal.—Divide the given height into five equal parts, the lower one is the height of the pedestal: divide the remaining four into five equal parts, and the upper one is the height of the entablature; divide the remaining four of these, into eight equal parts, and one will give the diameter of the column.

TO PROJECT THE IONIC ORDER TO A GIVEN HEIGHT.

For the column and entablature.—Divide the whole height into six equal parts, give the upper one to the entablature, divide the lower five into nine parts, and one will give the diameter of the column, to be divided into sixty minutes as a scale either to work or draw by.

For the column and entablature on a sub-plinth.—Divide the whole height into twelve equal parts, give the lower one to the sub-plinth, and proceed with the remaining eleven as above, which will give the height of the entablature, and the diameter of the column.

For the column, entablature, and pedestal.—In this, or any of the five Orders, the height of the pedestal is always one-fifth part of the entire height: therefore the height of the entablature, and diameter of the column, may be found as before.

TO DRAW, OR PROJECT THE CORINTHIAN ORDER.

To find the places of the stems of the leaves, divide the semi-plan into eight equal parts, and draw the plan of the leaves, with their stems; from the side of each stem draw the perpendicular lines to the elevation of the capital, and it will give the breadth of each stem on the front; the projection of the top of the leaves, is from a line joining the top of the abacus, and the astragal, at the bottom of the capital. All the different parts of this order being figured on the plate, will render any further explanation unnecessary. With respect to the measurement, the diameter of the column is one-tenth part of its height; the height of the entablature, and pedestal, are found in the same manner as in the Ionic order: that is, the height is divided into six equal parts, the upper one is for the height of the entablature, one half of which will of course be the diameter of the column. The pedestal takes one-fifth of the entire order, the sub-plinth one-twelfth. The diameter of the column is one-tenth of its height.

TO DRAW, OR SET OFF THE COMPOSITE ORDER.

The upper part of this order being the same as the Ionic angular capital, and the lower part for leaves, the same as the Corinthian: the general heights of the cornice, frieze, architrave, capital, shaft, and base, are consequently the same as that of the Corinthian; the diameter of the column is one-tenth part of its height, as in the Corinthian: the heights and projections of the members are obvious by the same rules.

The five orders, correctly drawn from the most approved examples, being given in three plates, might be there referred to as a further illustration of the present subject.

OF LINES FOR DESCRIBING PEDIMENTS.

To elucidate this subject, we have given at *Fig.* 1, *in architecture, Plate* 3, an elevation of a triangular pediment with its whole extent divided into nine equal parts, two of which are assigned for the perpendicular height of the pitch, set off from the upper line of the entire level cornice. If the pediment is intended to be open, divide the raking pitch into five equal parts, as in the figure, and give one from the centre each way, for the opening. The same proportions are to be adopted when the pediment is circular, whether it be close, or open; and, to describe the curve, nothing more is requisite, than to consider the raking lines of this *Figure* 1, as chord lines of a circular pediment, which being bisected, and lines drawn at right angles to the rake, will meet in the true centre from which the arch is to be described. In this example, the raking cornice consists only of the cima recta, which may be practised in cases where the tympan is required to be large, for the admission of groups, or other considerable ornaments. Commonly, however, the entire cornice is placed in the raking part, whether close or open; and it must ever be observed, that the face of the tympan, and that of the frieze of the level cornice, must be in a right line with each other. It must also be observed, with respect to pediments of the different orders, that when mutules or modillions, or dentiles, are introduced in the level or lower cornice, the same are likewise to be placed in the raking part, and in a line with them. And hence, in an open pediment, the due space assigned for the opening must always give way to a punctual regard to place dentile perpendicularly over dentile, from end to end of the pediment. But let it be remembered, that open pediments ought never to be adopted in exterior works.

In order to manage with accuracy the mitering of the raking mouldings with their respective returns, let it be observed that three different profiles are requisite, shewn at *Figure* 2, and 3, where *a* is the level, *b* the raking, and *c* the return moulding of an open pediment. Divide the contour of *a* into four or

or more equal parts, as at 1, 2, 3, &c. through which draw right lines parallel with the rake, and from the points 1, 2, 3, 4, draw lines parallel with the level moulding; then draw *e d* at *b* perpendicular to the rake, and take the projections 4, 4, &c. and place them on the rake at *b*, as shewn in the figure; and through these points describe the contour of the cima recta moulding of the raking cornice. Lastly at *c*, divide *f g* in the same manner as before at *a*, and let fall perpendiculars, which by intersecting their respective raking-lines, will give the true curve, as will evidently appear by inspecting *Figure*. 2, where observe, that the projections of the level moulding *a* are taken from level lines; but, at *b*, the same projections are laid on the raking-lines. Again also at *c*, 1, 2, 3, are on a level line, taken from 1, 2, 3, on the rake; and the same points may be found by taking the several lengths at 1, 2, 3, 4, on the raking lines of *a*, and placing them on the similar raking-lines at *c*. Some architects perform this operation by bisecting the hypothenusal lines of each moulding, which answering as chords to each curve, the centre at L, *Figure* 3, is found by the common method of describing a circle that will pass through three given points.

PROPORTIONS AND CHARACTERS OF THE ORDERS.

As the ancients vary much in the proportions they have assigned to each order, and as they not only differ from each other, but from themselves also, even in the same edifice; it is reasonable to suppose that they were not bound by any settled rules. M. Perrault has been at great pains to establish this point by chusing the mean of the two extremes, but it is surely much better to leave this to the judgement of the architect who, if frittered with rules, which confine him to certain proportions, will not be able to use his discretion or taste; so as to meet any new circumstances in the situation or building in which he may be employed. We do not, however, mean to say that the architect is to be left without compass or guide, but we agree with the before cited author, in thinking that the beauty of a column cannot be injured by a deviation, so trifling as a few minutes upon the height, and which the most accurate eye cannot detect. It is a remark worthy of notice, that the ancient architects did not follow in a servile manner the rules delivered by Vitruvius; yet certainly what he wrote were the rules by which they planned their great outline, or design, however they might vary the smaller or inferior parts of an edifice. To enumerate a few instances of variation: the temple of Minerva Pollias has six columns in front, yet is prostyle, although Vitruvius allows but four to this order. The temple of Jupiter Olympus at Athens has no more than eight columns in front, yet is hypæthral, to which Vitruvius gives ten columns in front. This is a variation recorded by himself, and without any particular notice of the violation of the rule; from which it should appear as not considered of much consequence.

This difference is also to be observed between the temples built by the Greeks, and those by the Romans. The rule of the former was, to give to the flanks one column more than double the number of those in front; thus an octastyle would have seventeen columns in the flanks, as to the temple of Minerva at Athens. The Romans, on the contrary, gave only double the number of intercolumniations; thus, to an hexastyle, they would make only eleven columns in the flanks, that is, ten intercolumniations, making two columns less in the flanks than the Greeks made; as is to the temple of Fortuna Virilis at Rome, and to the temple at Nismes in France. The walls of the cell were always placed opposite the columns of the pronaos, and posticum, according to the rule; at least we know of but one example to the contrary, which is the temple of Theseus at Athens. We thought it necessary to notice these instances of the variation of the ancient architects, that the researches and genius of modern times might not be led into error, or fettered by observing as law, that which was not adhered to by those we wish to imitate. We have given plates of some of the most approved examples of the orders, with the measurements of each part, as they are in the originals. In the modern proportions in the following descriptive account, we have followed Sir William Chambers's Treatise on Civil Architecture, which by comparison, will shew the variations of the moderns from the ancients.

TUSCAN ORDER.

Of the Tuscan order little historic can be said; its plainness of ornament gives it the first place in most treatises; there is no regular example of this among the remnants of antiquity. Piranisi has given a drawing of a Tuscan base found at Rome, but of what date is uncertain. Vitruvius, in an indistinct manner, has mentioned the general proportions, but through his whole book does not refer to one structure of this order. The Trajan and Antonine columns at Rome are reckoned of the Tuscan order, though they have eight diameters for their height; the torus and capitals are certainly more ornamented than is consistent with Tuscan plainness. The fluting to the necks also are after the most ancient Doric examples. It is somewhat singular there should be no remains of this order; and, were it not for what little Vitruvius has written of it, it certainly might have been lost to the moderns. The plainness of its appearance, no doubt, caused it to be neglected at Rome; but in no other place has been discovered any truly ancient example. Of the Doric there are unquestionably many remains of a very ancient date; which leads to a probable supposition that the Tuscan is no other than the Doric more simplified, or deprived of its ornaments to suit certain purposes, where strength and cheapness were wanted; nevertheless it is ap-

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plied with propriety and effect, to the entrance of cities, large gateways, and in military architecture, where dignity and massive strength are required. The profile of this order is selected from Palladio he having seen some remains in Italy, which might lead him to more just ideas of the style the ancients practised. It certainly derived its name, though not its origin, from the people of Tuscany, who were fond of introducing it into every large and stately edifice.

Sir William Chambers gives the Tuscan order the following proportions; "The height of the column is fourteen modules, or seven diameters; that of the whole entablature three modules and a half, which being divided into ten equal parts, three are for the height of the architrave, three for the frieze, and the remaining four for the cornice; the capital is in height one module; the base, including the lower cincture (which is peculiar to the measurement of this order) of the shaft, is also one module; and the shaft, with its upper cincture and astragal, is twelve modules; in interior decorations, the height of the column may be fourteen modules and a half, or even fifteen modules, which increase may be in the column only." It is customary in executing this order to diminish it one quarter, perhaps without sufficient reason; as its character of extraordinary strength would be better preserved by the usual diminution of one-eighth or one-sixth.

DORIC ORDER

Of this there are many examples still remaining; some of very high antiquity, and of proportions so dissimilar to the practice of later times, that one cannot help concluding they were produced before experience had matured the rules of art. In several buildings exhibited in the ruins of Pæstum, Ionia, and Athens, the height of the columns does not exceed four diameters, or at most four and a half; the low appearance of these in large buildings, must surely convince us, usefulness was regarded more than elegance of design. Indeed the history of the Doric order may be divided into three epocha. First, when the columns did not exceed four diameters in height, as to the temple called *Thoricion*, ten leagues from Athens; here the columns have four diameters, and are not fluted, except four and a half inches under the capital, with regular Doric fluting; the rest is smooth. Also to a temple at Corinth, where the columns are only three and a half diameters, and are fluted. To which may be added those remaining at Pæstum, in Italy; where to one temple the columns are four diameters high, to another about one-third less, and to the other about one-third more. The second era may be presumed, when the columns had not six diameters in height; as to the Propylea, or grand entrance into the citadel of Athens, to the temples of Minerva and Theseus at the same place, which were built in the flourishing time of Pericles, whose columns are only five and a quarter diameters high. Also the more ancient temple of Apollo, at Delos, where the columns have five diameters, and are smooth, or plain; having twenty channels or flutings three inches long in the neck, or top of the column, and as many at the foot, two inches long. The third point of time is when six or more diameters were allowed, as to the temple of Augustus at Athens; or as Stuart, on good evidence, calls it, "the entrance to a market," where six diameters are used. These are all without bases; in this division must be included the temple of Hercules, at Cora, where the columns have eight and three quarters diameter, and are on bases. Vitruvius allows this to be the most ancient order, and gives the following account of its origin; "Dorus, the son of Helenis and the nymph Optyce, built a temple in the ancient city of Argos, to the goddess Juno which happened to be of this order, but which then had no regular proportions; it derived its name from the patron of the building. This example, or order, was followed by all the cities of Achaia. Ion, the son of Xuthus afterwards built a temple in Asia, to Apollo Panionius, of this order; and, to render it more agreeable to the eye, he gave six diameters to the column, being guided therein by the example of nature, which has given to the height of man six times the length of his foot."

Modern practice allows eight diameters, and a base, which was never given to the Doric order by the ancients; this is another mark of its antiquity; for certainly the base is no less proper than elegant. Concerning the flutings, whether they were at first practised or not, is impossible to determine; the remains of this order of the oldest date have flutings. It appears probable, that, when any thing like ornament was wished to be added, the fluting of columns early presented itself. There are examples among the antiques of the column being squared off, or wrought with pans, as they are called, instead of hollows. Of this kind is the temple of Minerva at Syracuse, of very ancient Doric; the pillars are cut in pans or angles, and are without bases. The temple of Diana at the same place is also in the same style of Doric. To the temple of Hercules at Cora, the columns have the lower third part with pans, and the upper part of the shaft with the regular Doric fluting, which is a singular instance of mixture of style in antique columns. These columns have eight and three quarters diameters for their height, and stand upon bases of a very ungraceful form.

The triglyph, a characteristic mark of this order, has the appearance of art; the ends of projecting rafters will produce this effect, or near enough, to be improved into what we at present see them; the places assigned them also corroborate this idea. Vitruvius says, that in building, they laid the joists from the interior wall to the exterior parts, and as much of the joist as appeared unhandsome was sawed off, which, not having a pleasing effect, they made tablets like the triglyphs now in use, fixed them

them against the sawed ends, and painted them in wax, &c. Thus the triglyphs, interjoists, and metope, in Doric work, had their origin from the disposition of the timbers in the roof; afterwards, in other works, some made the rafters that were perpendicularly over the triglyphs to project out, and carved their projecture; hence, as the triglyphs arose from the disposition of the joists, so the mutules under the corona were derived from the projecture of the rafters; wherefore, in stone or marble structures, the mutules were represented declining, in imitation of the rafters; and also, on account of the droppings from the eaves, it is proper they should have such a declination. This also explains, the ornament and situation of the guttæ, or drops. The ornaments on the metope, or the space between the triglyphs, may have been originally trophies of the Deity, or implements of sacrifice placed there; the bull's skull is peculiar to the Doric order. M. Winkelman has taken some pains to prove, from a passage in Euripides, that the metopes or spaces between the triglyphs were open in the most ancient temples. How this may have been, cannot now be determined; those structures which remain have the space filled with masonry.

The profile we have given is taken from Palladio, which has been considered as a just proportion for this masculine order.

The modern proportions, from the before-cited author, are as follows. The height of the column, including its capital and base, is sixteen modules; the height of the entablature, four modules; which being divided into eight parts, two are for the architrave, three for the frieze, and three for the cornice; the base is one module in height; the capital thirty-two minutes, or a little more.

IONIC ORDER.

The origin of this order is accounted for by Vitruvius, in the following manner:—"Ion, (the same as before-mentioned,) building a temple to Diana, and seeking some new manner to render it more elegant, had recourse as before in the Doric order, to the human figure; and gave to this new order a feminine delicacy; thus he was the first who gave eight diameters to a column, that the aspect might be more pleasing; and, that its appearance might be more lofty, he added a base, in imitation of a shoe; the volutes, like locks or plaits of hair, hanging on each side, he gave to the capital, ornamented with fruits, or flowers, in festoons and furrows; or flutings down the column were wrought, resembling the folds or plaits of a matron's garment. Thus he invented two kinds of columns, in the Doric imitating a manly robust appearance, without ornament; in the Ionic, regarding a female delicacy, accompanied with ornaments pleasing and elegant. Succeeding architects, much approving the taste and ingenuity of this design, allowed eight diameters and a half to this order." Vitruvius records an anecdote much in praise of the Ionic order, in the following words: "the difficulty attending the proper adjustment of the mutules, metopes, and triglyphs, in Doric structures, was such, as frequently to be a cause of much inconvenience and trouble to architects, in large buildings, and also rendered their aspect confused and embarrassing; on which account, and the massy appearance of the Doric column, it was thought improper for sacred buildings: of this opinion were Tarchenius and Pytheus, with many ancient architects; also the celebrated Hermogenes, who, when he was building the temple of Bacchus at Teos, rejected the Doric, though all the marbles were ready cut, and in its stead erected a temple of the Ionic order. Our two examples of this order are taken from the two celebrated edifices, the temple of Fortuna Virilis, and the theatre of Marcellus at Rome. The modern Ionic has the volute of the capital executed on an angular plan, the same as in the Composite order; so that, viewed every way, it has the same appearance; this differs from the general mode of the antiques, which was to have the volutes parallel. And to Michael Angelo this was attributed as a new invention; but examples are found in the capitals of the angle columns in the temple of Erictheus at Athens, and in the temple of Fortuna Virilis at Rome. Piranasi has endeavoured to prove the first idea of the Ionic volute to have been derived from shells; and certainly many pleasing forms of convolution may be obtained from the section of shells.

The standard of the modern proportions is as follows: The height of the column is eighteen modules, and that of the entablature four modules and a half, or one quarter the height of the column, as in the other orders, which is a trifle less than in the regular antique Ionics: the capital is twenty-one minutes, and the base thirty minutes in height; the shaft of the column may be plain, or fluted, with twenty or twenty-four flutings, whose plan may be a trifle more than a semicircle, because they then appear more distinct; and the fillet or interval between them must not be broader than one-third of the breadth of the fluting, nor narrower than one quarter thereof; the ornaments of the capital are to correspond with the flutings of the shaft; and there must be an ove above the middle of arch fluting. The entablature being divided into ten equal parts, three are for the architrave, three for the frieze, and four for the cornice. In interior decorations, where much delicacy is required, the height of the entablature may be reduced to one-fifth of the height of the column.

CORINTHIAN ORDER.

This differs from the Ionic only in its capital; the Ionic capital having no more than one-third of the diameter of the column for its height; but the Corinthian capital is allowed one entire diameter, which gives to the column a noble but delicate grandeur. The other members placed on the Corinthian

rinthian pillar, are common to the Doric and Ionic orders; for it has no particular species of ornament peculiar to its cornice; sometimes it has the Doric mutules and triglyphs in the architrave; sometimes an Ionic frieze, with dentiles in the cornice; in a manner, it is no more than a third order, risen out of the former two, which has nothing peculiar to itself but the capital. Its origin Vitruvius records as follows: "A marriageable young lady of Corinth fell ill, and died; after the interment, her nurse collected together sundry ornaments with which she used to be pleased, and, putting them into a basket, placed it near her tomb; and, lest they should be injured by the weather, she covered the basket with a tile. It happened the basket was placed on a root of acanthus, which in spring shot forth its leaves; these, running up the side of the basket, naturally formed a kind of volute, in the turn given by the tile to the leaves. Happily Callimachus, a most ingenious sculptor, passing that way, was struck with the beauty, elegance, and novelty of the basket surrounded by the acanthus leaves; and, according to this idea or example, he afterwards made columns for the Corinthians, ordaining the proportions such as constitute the Corinthian order." Vitruvius, in the foregoing account, forgot the peculiarities of the Corinthian cornice, or the entablature to that order was not then practised in the manner we find remaining among ancient buildings; for to this cornice the modilion is ever an attendant. But exactly according to this description of Vitruvius, is the cornice of the portico at Athens, called Poikilie, as represented by the indefatigable Stuart, in his valuable antiquities of that ancient city.

The beauty and elegance of this order have rendered it famous, and the many examples existing among the fragments of antiquity, sufficiently evince the great esteem with which it was regarded. The ravages of cruel and desolating war, however, have not left us one remain of this order, from among the many celebrated examples which the city of Corinth possessed, where arts of every kind, and particularly architecture, eminently flourished and were carried to perfection. In later times the conduct of Lucius Mummius, in the destruction of that polished people and city, would have justly been considered as the grossest barbarism; the temples, the sacred buildings, were destroyed, and levelled with the ground; so that at one stroke the works of ages were desolated, the labours and ingenuity of thousands were destroyed, and posterity deprived of every trace of this order, in the place of its nativity and nurture. Although Rome would not suffer Corinth to exist as a rival city, there is no doubt but she deigned to follow the rules and laws of art established by her vanquished enemy, especially in architecture. The elegance and purity of style in many of her buildings clearly evince Grecian ingenuity and refinement.

The profile we have given, is according to Palladio's measurements; the universal celebrity of this master, pointed it out as a proper example. The moderns have adopted the following proportions; the column is twenty modules in height; the entablature five modules; the base one module, and may be either Attic or Corinthian; the capital has seventy minutes in height; the proportion of the members of the entablature is the same as in the Tuscan and Ionic orders. If the entablature is enriched, the shaft of the column may be fluted, and the flutings may be filled to one-third part of their height with cabling, which will strengthen the lower part of the column, and make it less liable to injury. In very rich interior decorations, the cabling may be composed of reeds, ribbands, husks, flowers, &c. The capital is enriched with olive-leaves, as almost all the antiques at Rome of this order are; the acanthus is seldom employed but in the Composite order: the entablature may be reduced to two-ninths, or one-fifth of the height of the column; in which case it is best to use the Ionic entablature, or reduce the dentiles of the cornice, &c.

COMPOSITE ORDER.

The Composite, or Roman order, seems to owe its origin to that constant solicitude after novelty, which ever renders the mind of man restless in enlightened and highly cultivated ages. The desire of variety and novelty, either of new invention, or combination, probably engaged the Roman architects to unite with the proportions and enrichments of the Corinthian order, the angular volute of the Ionic, and by this union to compose a new order. The introduction of the angular Ionic volute, and the omission of the upper row of leaves in the capital, certainly give it a more bold and noble aspect than that of the Corinthian capital, yet different from any of the other orders, possessing an elegance and projection very pleasing, and may be used with very agreeable and happy effects. There are many examples remaining at Rome, which shew the general estimation of this order, in the height of its splendour and prosperity. In their triumphal arches, it was used with good effect, where it produced an agreeable boldness, uniting elegance and ornament. The example given in the annexed plate, is after Vignola; the justness of the proportions, with the elegance of the ornaments, mark it as a proper standard for the Composite order. The proportions adapted to it by the moderns are as follow: the height of the column is twenty modules; and that of the entablature five modules; the capital has seventy minutes in height; the base measures the same as in the Doric and Ionic orders; and, as the module is less, all its parts will of course be more delicate; the shaft may be enriched with flutings, to the number of twenty or twenty-four, as in the Ionic order; there is no reason why they should be augmented. The principal members of the entablature may have the same proportions as the two former orders, viz. being divided into ten equal parts, three

three are for the height of the architrave, three for the frieze, and four for the cornice.

We may add here, more to complete the history than to recommend their use, that there are ancient examples of oval columns; where the circle of the column is elongated by a broad plain space on the two opposite sides of the shaft. Of this kind were some fragments found in the island of Delos, by M. le Roy. There are two others at La Trinite du Mont, at Rome: also in the tomb near Mylassa, in Greece, according to M. de Choiseul, this elegant structure is very perfect; is of a square form, on a basement; the pillars are insulated, and support a vaulted ceiling highly enriched; each front has two oval fluted columns with the narrow face outwards; at the angles are pilasters having the same enrichments as the columns; the capitals are Composite, and the volutes are omitted. This elegant little *morceau* is of white marble, and about nineteen feet square.

It has often been contended, that, strictly speaking, there are only three orders in architecture, namely, the Doric, Ionic, and Corinthian; the other two, viz. the Tuscan and Composite, being only varieties. And perhaps it would simplify and facilitate the study of architecture, were this restriction universally to take place. The only circumstances that can serve to distinguish one order from another, are the form of the column, and its destination. To make the first a distinguishing mark, without regard to the other, would be to multiply orders without end. Destination is more limited, and it leads us to distinguish three kinds of orders; one plain and strong, for the purpose of supporting plain and massy buildings; one delicate and graceful, for sustaining buildings of that character; and between these a third, for supporting buildings of a mixed nature. So that, if destination alone were to be regarded, the Tuscan is of the same order with the Doric, and the Composite with the Corinthian.

An order may be divided into two parts, the column, including the plinth of its base, with the abacus of the capital; and the entablature, which includes all above the capital, and may be divided, in the large, into the architrave, the frieze, and the cornice.

By examining the antiques, it will be found, that, in all their profiles, the cyma and the cavetto are constantly used as finishings, and never applied where strength is required; that the ovolo and talon are always employed as supporters to the essential members of the composition, such as the modillions, dentiles, and corona; that the chief use of the torus and astragal, is to fortify the tops and bottoms of columns, and sometimes pedestals, where they are frequently cut in the form of ropes; and that the scotia is employed only to seperate the members of bases, for which purpose the fillet is also used, not only in bases, but in all kinds of profiles. An assemblage of essential parts and mouldings, is termed a profile; on the choice, disposition, and proportion of these, depends the beauty or deformity of the profile. The most perfect are, such as are composed of few mouldings, varied both in form and size, fitly applied with regard to their uses, and so disposed, that the straight and curved ones succeed each other alternately. In every profile there should be a predominant member, to which all the others ought to be subservient, and seem made either to support, to fortify, or to shelter it from the injury of the weather, as in a cornice where the corona is principal, the cyma or cavetto cover it, and the modillions, dentiles, ovolo, and talon, support it.

When ornaments are employed to adorn the mouldings, some of them should be left plain, in order to form a proper repose; for, when all are enriched, the figure of the profile is lost. In a cornice the corona should not be ornamented, nor the modillion band; neither should the different facias of architraves, the plinths of columns, fillets, nor scarcely any square member, be carved; for they are generally speaking, either principal in the composition, or used as boundaries to other parts; in either of which cases, their figures should be distinct and unembarassed. The dentile band should remain uncut, where the ovolo and talon immediately above and below it are enriched; for, when the dentiles are marked, particularly if they be small, the three members are confounded together, and, being covered with ornament, are much too rich for the rest of the composition; a fault carefully to be avoided, as the just and equal distribution of enrichments is on all occasions to be attended to. For, in effect, the ornaments of sculpture in architecture, are like diamonds in a lady's dress, with which it would be absurd to cover her face, and other parts that are in themselves beautiful. When mouldings of the same form and size are employed in one profile, they should be enriched with the same kind of ornaments. It must be observed, that all the ornaments of mouldings are to be regularly disposed, and answering perpendicularly above each other; the middles of the modillions, dentiles, oves, and other ornaments, all in a line; for nothing is more confused and unseemly, than to distribute them without any kind of order. The larger parts are to regulate the smaller; all the ornaments in the entablature are to be governed by the modillions or mutules; and these are to be dependant upon the intervals of the columns, and so disposed, that one of them may correspond with the axis of each column. It is farther to be observed, that the ornaments must partake of the character of the order which they enrich; and those used in the Doric and Ionic orders must be of a simpler kind, and grosser make, than those employed in the Composite and Corinthian. In the exterior, whatever does not contribute to the general effect of the whole build-

 ing,

ing, is in a great measure useless, and an expence that might more judiciously be employed in places where it could be more attended to. The parts that are in themselves large, and so formed and disposed as to receive broad masses and strong impressions of light and shade, will of course excite great ideas; but, if they are broken into a number of small divisions, and their surface so varied as to catch a thousand impressions of light, demi-tint, and darkness, the whole will be confused, trifling, and incapable of causing any great emotions.

The appearance of columns is often varied by adding rusticated cinctures at equal (or other) distances to a column: this is a modern invention, which gives a very unnatural appearance, and disguises the noble figure of the column. Rustic work is with greater propriety, and better effect, introduced into large entrances, parks, and gardens; also into grottos, baths, or fountains, where an irregular and rough appearance better suits the place and purpose. Le Clerk says, these kind of rustic ornaments are never to be imitated, excepting in the gates of citadels or prisons, in order to render their entrances more rugged and frightful.

The flutings of columns are sometimes wrought round, or spirally on the column; there is an ancient example of this, in a small temple below Trevi, in Italy, the plan and elevation of which are given by Palladio, where, of four columns in front, two have their columns spirally, and the two centre ones are wrought with leaves on the shaft.

The rule for the diminution of columns has ever varied; the ancients frequently diminished the column, from the very foot, or from one-quarter or one-third of its height; the latter method is now generally practised; the diminution should be seldom less than one-eighth part of the lower diameter of the shaft, nor more than one-sixth, this latter is the more graceful: some, by way of giving a better contour or appearance, allow a small swell, or bellying, in the lower part of the middle division of the pillar.

It will here be proper to give the general rules to be observed in pedestals, where it is necessary to introduce them. They consist of three principal parts; the base, the dye, and the cornice. A determinate rule, however, cannot be given, as they must be made to vary in height according to the circumstances which render them useful; they have ever been considered as mere auxiliaries, to give height, and elevate the column above surrounding objects which impede its view. When they are used by choice, it is common to give them one-third, or one-quarter part of the height of the column and entablature, which is thus divided: of nine equal parts, two are for the base, one for the cornice, the remaining six for the dye, of the pedestal, which is equal in size to the plinth of the column; the enrichments should be regulated by those of the entablature, &c. whereby they are made subservient to each distinct order. When columns are in couples, if pedestals are used, they should have but one; also in a colonnade or peristyle there should be but one pedestal continued, having breaks or projections in the cornice, &c. so that each column may seem to have its particular pedestal.

Each column has its particular base. The Tuscan base is the most simple, having only a torus and plinth. The Doric base has an astragal more than the Tuscan. To the Ionic base the torus is larger on a double scotia, with two astragals between. The Corinthian base has two toruses, two scotias, and two astragals. The Composite base has one astragal less than the Corinthian. The Attic base consists of two toruses and a scotia, and is applicable to every order except the Tuscan, which has its particular base

Pilasters differ from columns only in their plan; which is a square, as that of columne is round. Their bases, capitals, and entablatures, have the same parts, with the same heights and projections, as those of columns; they are also distinguished in the same manner, by the names of Tuscan, Doric, Ionic, Corinthian, and Composite. Th column is undoubtedly more perfect than the pilaster; however, they may be employed with great propriety on many occasions. Some authors declaim against pilasters, because, according to them, they do not admit of diminution. But this is a mistake; there are many instances, in the remains of antiquity, of their being diminished. Scamozzi always gives his pilasters the same diminution as his columns; Palladio and Inigo Jones have likewise diminished them in many of their buildings. Pilasters are employed in churches, galleries, halls, and other interior decorations, to save room; for, as they seldom project beyond the solid wall, above one-quarter of their diameter, they do not occupy near so much space as columns. They are likewise used in exterior decorations; sometimes alone, instead of columns, on account of their being less expensive; and sometimes they accompany columns, being placed behind them to support the architraves, where they enter the building, as in the Pantheon at Rome; or, in the same line with them, to fortify the angles, as in the portico of Septimius. When pilasters are used alone, they should project one-quarter of their diameter beyond the walls. When placed behind columns, especially if they be very near them, they need not project above one eighth of their diameter. But, when placed on a line with columns, their projection must be regulated by that of the columns; and consequently it can never be less than a semi-diameter, even when the columns are engaged as much as possible. The shafts of pilasters are frequently adorned with flutings in the same manner as those of columns; the plan of which may be a trifle more than a semi-circle; their number must be seven on each face, which makes them nearly of the same size with

with those of columns. The intervals, or fillets, must either be one-third or one-fourth of the fluting in breadth. The capitals of pilasters are profiled nearly in the same manner as those of columns.

Attics had their origin in Athens, where it was for many ages a rule in building to conceal the roof. For this purpose, nothing served so well as a kind of low or little order ranged in a continued line, singly, or with the interruption of balusters; which rising above the rest of the work and before the roof, hid it perfectly, and placed something agreeable in view. The place of attics, therefore, is at the uppermost extremity of a building, to which they serve as a crown, or very properly make a finishing for the other orders when they have been used in the structure. They must never stand under any thing except such ornaments as are placed at the very top. These attics should never exceed in height one-third of the height of the order on which they are placed, nor be less than one-quarter of it. The base, dye, and cornice, of which they are composed, may bear the same proportions to each other as those of pedestals do; and the base and cornice may be composed of the same mouldings as those pedestals. Sometimes the attic is continued throughout; at others, it projects, and forms a pilaster over each column of the order. The breadth of this pilaster is seldom made narrower than the upper diameter of the column below it, and never broader. Its projection may be equal to one-quarter of its breadth.

Besides columns and pilasters, it is sometimes customary to employ representations of the human figure, to support entablatures in buildings. The male figures are called Persians; and the female, Carians, or Caryatides. The Persians are so called from a victory gained over the Persians by Pausanias, who having brought home spoils and trophies to the Athenians, they fixed upon Persian figures for those which should support entablatures, and thus kept in mind that there were once Persian slaves in Athens. To represent these conquered people in the lowest state possible, they loaded them with the heaviest entablature, viz. that of the Doric order. In process of time, however, other figures besides those of Persians were introduced, and other entablatures put over them; but the name was still retained. The proper Caryatides are women dressed in long robes, after the Asiatic manner; and the origin of the device was as follows: The Carians had been long at war with the Athenians, but, being at length totally vanquished, their wives were led away captives; and, to perpetuate the memory of this event, trophies were erected, in which figures of women dressed in the Caryatic manner, were used to support entablatures like the Persians; and though other female figures were afterwards used in the same manner, the name of Caryatides was always retained.

The ancients made frequent use of Persians and Caryatides, and delighted in diversifying them a thousand ways. The modern artists have followed their example; and there is a great variety of compositions of this kind to be met with in different parts of Europe. The Caryatides, or female figures, should never much exceed the human size. But the Persians, or male figures, may be of any size; and the larger the better, as they will strike the beholder with the greater awe and astonishment. Persians may be used with propriety in arsenals, galleries of armour, &c. under the figures of captives, heroic virtues, &c. Their entablature ought to be Doric, and bear the same proportion to them as to columns of the same height. The entablature for Caryatides ought to be either Ionic or Corinthian according as the character of the figure is more or less delicate.

Termini are sometimes employed, instead of Persians or Caryatides, to support the entablatures of monuments, chimney-pieces, and such-like compositions. These figures owe their origin to the stones used by the ancients to mark the limits of particular possessions. Numa Pompilius, to render these inviolable, consecrated the Terminus into a deity, and instituted festivals and sacrifices to his honour. In a short time, what was formerly only large upright stones, were represented in human shape; and afterwards introduced as ornaments to temples and other buildings. The Termini are now principally used as ornaments for gardens and fields.

OF THE SACRED BUILDINGS OF THE ANCIENTS.

The elegance and magnificence of a structure depending very much on the proper placing of the columns, we shall add the rules laid down by Vitruvius, as observed by the ancients, and allowed by the moderns, in the disposition of columns, called by that writer the five species of building; which are as follow;—1st, the Pycnostyle, that is thick of columns; 2d, the Systyle, that are a little wider; 3d, the Diastyle, still wider; 4th, the Arœostyle, more distant than is proper; and 5th, the Eustyle, which is the proper distance.

To the pycnostyle, the distance of the intercolumniations, is one diameter and a half of the column; as in the temple of the divine Julius; the temple of Venus in Cæsar's Forum, and many others after the same manner. The systyle has two diameters of the column between the intercolumniation, and the plinths of the base are equal to the space which is between two plinths; as in the temple of Fortuna Equestris, near the Stone Theatre; and others made after the same proprotions. Both these sorts are inconvenient; by the frequency of the columns, the view of the door, and the signs or trophies of the deity, are hid, and the narrowness of the porch is inconvenient for walking. The diastyle has this distribution, viz. three diameters of the columns between the intercolumniations, as in the temple

temple of Apollo and Diana. This has its inconveniences; because the architrave, on account of the distance between the columns, is liable to break. In the aræostyle they use neither stone nor marble, but make the beams of durable timber. This kind of building is straggling and heavy, low and broad. The pinnacles are generally ornamented with fictile or earthen-ware, or brass gilt after the Tuscan manner, as in the Circus Maximus at the temple of Ceres, and in Pompey's temple of Hercules, and also in the capitol. The eustyle manner, for its usefulness, beauty, and durability, merits every commendation. It is formed by allowing to the distance of the intercolumniations two diameters and a quarter, and to the middle intercolumniation only, both before and behind three diameters. Thus the figure has a beautiful aspect, is accessible, without impediment, and round the cell is a stately ambulatory. The rule is this; the front of the building of it is tetrastyle (four columns), is divided into eleven parts and a half, without reckoning the projection of the base of the column. If it is hexastyle (six columns), it is divided into eighteen parts. If it is octastyle (eight columns), it is divided into twenty-four parts and a half. Of these parts, one, whether the building be tetrastyle, hexastyle, or octastyle, shall be a module, which is to be the thickness of a column. Each intercolumniation, except the middle one, must be two modules and a quarter; the middle one shall have three modules both before and behind; the height of the columns shall be eight modules and a half; by this division of the intercolumniation, the columns have a just proportion. Rome affords no example of this kind; but at Teos in Asia is one, the temple of Bacchus, which is octastyle.

Hermogenes was the first inventor of these proportions; he also first used the octastyle pseudodipteral; he first contrived to take away, without injuring the beauty, the inferior range of columns in the dipteral (which are thirty-four), thereby very much decreasing both the labour and expence; this also gave a very large ambulatory round the cell, and, without missing the superfluity, preserved the majesty of the whole; for the walls and the columns were thus first disposed, that the view, on account of the asperity (asperitas) of the intercolumniation, should have more majesty; besides, it has this convenience of sheltering a great many persons from rain, as well round, as within the cell, which includes a great space. This disposition of pseudodipteral buildings was first discovered by the labour of the great and discerning spirit of Hermogenes; which, like a fountain, will serve posterity from whence to draw rules for the science of architecture.

The columns to the aræostyle should have for their thickness one-eighth part of their height. For the diastyle, the height of the column is to be divided into eight parts and a half; one part for the thickness of the column. For the systyle, the height shall be divided into nine parts and a half; one part for the thickness of the column. Also for the pycnostyle, the height shall be divided into ten parts; one part for the thickness of the column. The eustyle also is divided into eight parts and a half, the same as the diastyle; one part is given for the thickness of the column; and for the solidity of its parts it shall have its proper intercolumniation. As the space between the columns increases, so ought also the thickness of the columns. If it is aræostyle, and they should only have a ninth or tenth part for their thickness, they will then appear tall and slender, on account of the length of the intervals; for the aisle will in appearance diminish the thickness of the columns. On the contrary, if it is pycnostyle, and the columns have an eighth part of their thickness, they have a clumsy and ungraceful appearance, on account of the frequency of the columns, and the narrowness of the intervals: for this reason, the symmetry and proportion of each order should be attended to. Also the thickness of the corner columns must be increased one-fiftieth part; for, by the great surrounding space, they will appear smaller to the view, and it is necessary art should rectify this defect of vision.

APPLICATION OF THE FIVE ORDERS IN BUILDING.

Among the ancients, as we have already seen, the use of the orders was very frequent, many of their cities were provided with spacious porticos, their temples were surrounded with colonnades, and their theatres, baths, basilicas, triumphal arches, mausoleums, bridges, and other public buildings, were profusedly enriched with columns; as were likewise the courts, vestibules, and halls, of their private villas and houses.

In imitation of the ancients, the moderns have made the orders of architecture the principal ornaments of their structures. We find them employed in almost every building of consequence; where they are sometimes merely ornamental, but at other times of real use, serving to support the incumbent weight of any structure erected upon them. On some occasions they are employed alone; the whole composition consisting only of one or more ranges of columns, with their entablature. Upon other occasions the intervals between the columns are filled up and adorned with arches, doors, windows, niches, statues, basso-relievos, and other similar inventions. The columns are either placed immediately on the pavement, or raised on plinths, pedestals, or basements; either engaged in the walls of the building, or standing detached, either near, or at some distance from them; and frequently different orders are placed one above another, or intermixed with each other on the same level. In these, and in all other cases, in which the orders are introduced, particular measures, rules, and precautions, are

are to be observed, which we shall now endeavour to explain and illustrate.

OF INTERCOLUMNIATIONS AND ARCADES.

Columns are either engaged or insulated; and, when insulated or detached from the wall, they are either very near, or at a considerable distance from it. When they are placed at a considerable distance from the wall, they are destined to support the entablature; and their distance from each other should be consistant both with their real and apparent solidity. Engaged columns are attached to the wall, and are not limited in their intercolumniations, as they depend on the breadth of the arches, doors, windows, niches, or other decorations, placed in them.

Palladio says, the intercolumniation of the Tuscan order was adapted to farm-houses and other rustic works, as it afforded a passage for carts, and was attended with the least expence. In structures built entirely of stone, they used a shorter interval, more suitable to the length of their marble blocks, and more agreeable to the ponderous fabric which they occasionally supported; for which reason the diastyle and eustyle modes were sometimes applied to this order. The moderns have indeed adopted these two as their general rule, and apply them to every order except the Doric. The areostyle, however, is sometimes, by a modern contrivance authorised by a few examples of the ancients, introduced in porticos and peristyles. This mode of the areostyle is from Perrault, and is managed by placing two columns together at the angles, so close as to admit the two capitals nearly into contact. This manner which is termed grouping, takes off from the excessive width of this kind of interval, whilst it adds to it both real and apparent strength, as is exemplified in St. Paul's church in London, and in the palace of the Louvre at Paris.

Arches, or arcades, are not so magnificent as colonades; but they are more solid and less expensive. They are proper for triumphal entrances, gates of cities, of palaces, of gardens, and of parks, and, in general for all openings that require an extraordinary breadth. There are various manners of adorning arches. Sometimes their piers are rusticated; sometimes they are adorned with pilasters, termini, or caryatides; and sometimes they are made sufficiently broad to admit niches or windows. The circular part of the arch is either surrounded with rustic key-stones, or with an archivolt enriched with mouldings; which, in the middle, is sometimes interrupted by a console, or mask, serving at the same time as a key to the arch, and as a support to the architrave of the order. The archivolt is sometimes supported by an impost at the head of the pier; and at others by columns placed on each side of it, with a regular entablature, or architrave and cornice. There are also instances of arcades without piers: the arches being turned on single columns, as in the temple of Faunus at Rome, &c. But this practice ought to be seldom imitated, as it is neither solid nor handsome. When, however, arcades are employed to ornament domestic apartments, the breadth of the pier need not exceed one-quarter of the opening of the arch. When arches are closed up to receive doors, windows, or niches, the recess should be sufficient to contain all the projections of what is placed therein, otherwise their appearance is clumsy, and will become too principal, which produces a bad effect in the composition.

When arches are large, the key-stone should never be omitted, but cut in the form of a console, and carried close under the soffit of the architrave, which, on account of its extraordinary length, requires a support in the middle. The imposts of arches should never be omitted; at least, if they be, a platform ought to supply their place. If columns are employed without pedestals in arcades, they should always be raised on a plinth. In arches of great magnitude, the circular part ought not to spring immediately from the impost, but take its rise at such a distance above it as is necessary in order to have the whole curve seen at the proper point of view.

The void or aperture of arches should never be higher, nor much lower, than double their breadth; the breadth of the pier should seldom exceed two-thirds, nor be less than one-third, of the breadth of the arch; and the angular pier ought to be broader than the others, by one-half, one-third, or one-fourth; the impost should not be more than one-seventh, nor less than one-ninth, of the aperture; and the archivolt must not be more than one-eighth, nor less than one-tenth, of it. The breadth of the console must, at the bottom, be equal to that of the archivolt; and its sides must be drawn from the centre of the arch the length of it must not be less than one and a half of its smallest breadth, nor more than double. The thickness of the pier depends on the breadth of the portico; for it must be strong enough to resist the pressure of its vault. But, to give beauty to the building, it should not be less than one-quarter of the breadth of the arch, nor more than one-third.

The proportions peculiar to the Tuscan arch, without pedestals, are as follow: In height, their aperture is seven diameters and a quarter, in width four, and from centre to centre of the columns six diameters. According to the preceding remarks, the archivolt and imposts are half a diameter, and from the top of the archivolt to the under side of the architrave should not be less than fifteen minutes. The breadth of the key-stone at the bottom is equal to its archivolt; and its spreading sides are determined by lines drawn from the centre of the arch. The Tuscan arch with pedestals is in width four and a half, and in height eight diameters and a quarter; and from centre to centre of each pier is

six and three-quarters. In every other particular they are subject to the preceding rules.

The intercolumniation of the Doric order is often attended with peculiar difficulty, arising from the strict regard that is necessarily paid to the width of the triglyph, and the perfectly-square form of the metopes, or their intervals. Besides that, it is absolutely requisite, that a triglyph should be placed exactly over the centre of every column. For these reasons, the mutules and triglyphs have been omitted in capital works, both ancient and modern, as in the Coliseum at Rome, and the Royal Hospital at Greenwich. Pallado has, however, given one instance of an ancient temple with angular triglyphs. This structure, which he terms the Temple of Piety, is mentioned by Vitruvius, with an eye to the difficulty occasioned by the triglyphs being thus placed; which reduces the intercolumniation of the two angular columns to one diameter and a quarter, which is less than the pycnostyle. The next intercolumniation is still greater, approaching nearly to the pireostyle, as is evidently necessary to bring the triglyph over the centre of the third column from the angle. The next, which is the centre intercolumniation, and faces the entrance of the temple, is rather more than eustyle, or two diameters and a quarter; and has, in the metope, ditriglyph. But the intervals between the triglyph are much too narrow for their heights, so as to produce an unfavourable effect. The other spaces are monotriglyph, and are perfect. The regular intercolumniation of the Doric order in the monotriglyph, or pycnostyle, which admits of one between two columns. The ditriglyph, or eustyle, admits two; and the aræostyle is tritriglyph, or consisting of three; but the most perfect of these is the ditriglyph.

When the capitals and bases of coupled Doric columns have their proper projections, and are at any distance from each other, the metope between them will be rather too wide; but that may be avoided by confining the projections, or making the triglyph one minute more than it really should be, and placing or removing its centre a minute within the axis of the column, which trifling differences will not be perceived without the nicest examination. In small buildings, such as temples and other similar ornaments for gardens, the intercolumniations may be determined without paying a strict regard to the general rules for the distances of columns; always observing, however, that such works must have an interval that will admit of an easy passage between them.

Doric arches, without pedestals, are seven diameters and three-fourths high, and in width four diameters and fifteen minutes. The piers are two modules in front, and in thickness one module, twenty-two minutes and a half; or in proportion to their distance from the wall. From centre to centre of each pier is six diameters and fifteen minutes.

Arches of this order, with pedestals, have their apertures in height nine diameters and thirty minutes, and in their width five diameters fifteen minutes. The piers are two diameters and fifteen minutes wide in front, and from centre to centre of each is seven diameters fifteen minutes.

With respect to the intercolumniation of the Ionic, Corinthian, and Composite orders, what has been already observed on the subject will suffice: and, as to the arches peculiar to each order, all that is necessary, after what has been remarked on the two preceding orders, is a careful inspection of the plates, whereon all the dimensions are ascertained.

OF ORDERS UPON ORDERS, AND OF BASEMENTS.

When, in a building, two or more orders are employed, one above another, the laws of solidity require the strongest should be placed lowermost. Hence the Tuscan must support the Doric, the Doric the Ionic, the Ionic the Composite or Corinthian, and the Composite the Corinthian. This rule, however, is not strictly adhered to. Most authors place the Composite above the Corinthian. There are likewise examples where the same order is repeated, as in the theatre of Statilus Taurus, and in the Coliseum, and others, where an intermediate order is omitted, and the Ionic placed on the Tuscan, or the Corinthian on the Doric. But none of these practices ought to be imitated. In placing columns above one another, the axis of all the columns ought to correspond, or be in the same perpendicular line, at least in front.

With regard to the proportions of columns placed above each other, Scamozzi's rule, that the lower diameter of the superior column should constantly be one, equal to the upper diameter of the inferior is universally esteemed the best, and gives all the columns the appearance of one long tapering tree, cut into several pieces. In this country, there are few examples of more than two stories of columns in the same elevation; and though in Italy, and other parts of Europe, we frequently meet with three, and sometimes more, yet it is a practice by no means to be imitated; for there is no possibility of avoiding many striking inconsistencies, or of preserving the character of each order in its intercolumnial decorations.

Instead of employing several orders one above the other, the ground-floor is more judiciously made in the form of a basement, on which the order that decorates the principal story is placed. The proportions of these basements are not fixed, but depend on the nature of the rooms on the ground floor. In the place of the Porti in Vicenza, the height of the basement is equal to that of the order. In some buildings, its height exceeds two-thirds of that of the order: and, in others, only half the height of the order. It is not, however, adviseable to make the basement higher than the order it supports; neither should it be lower than one-half of the order.

The

The usual method of decorating basements is with rustics of different kinds. The best, where neatness and finishing is aimed at, are such as have a smooth surface. Their height, including the joint, should never be less, nor much more, than half a module of the order placed on the basement. Their figure may be from a square to a sesquialtera; and their joints may be either square or chamfered. The square ones should not be broader than one-eighth of the height of the rustic, nor narrower than one-tenth; and their depth must be equal to their breadth; those that are chamfered must form a rectangle; and the breadth of the whole joint may be from one-fourth to one-third of the height of the flat surface of the rustic.

OF PEDIMENTS.

Pediments among the Romans, were used only as coverings to their sacred buildings, till Cæsar obtained leave to cover his house with a pointed roof, after the manner of temples. In the remains of antiquity we meet with two kinds of pediments, the triangular and circular. The former of these are promiscuously applied to cover small or large bodies: but the latter, being of a heavier figure, are only used to cover doors, niches, windows, or gates.

As a pediment represents the roof, it should never be employed but as a finishing to the whole composition. The ancients introduced but few pediments into their buildings, usually contenting themselves with a single one to adorn the middle or principal part. But some of the moderns, and particularly the Italians, have been so immoderately fond of them, that their buildings frequently consist of scarcely any thing else. The girder being a necessary part in the construction of a roof, it is an impropriety to intermit the horizontal entablature of a pediment, by which it is represented, to make room for a niche, an arch, or a window.

In regular architecture, no other form of pediments can be admitted besides the triangular and circular. Both of them are beautiful; and when a considerable number of pediments are introduced, as when a range of windows are adorned with them, these two figures may be used alternately, as in the niches of the Pantheon, and in those of the temple of Diana at Nismes. The proportion of pediments depends upon their size: for the same proportions will not do in all cases. When the base of the pediment is short, its height must be increased; and, when the pediment is long, the height must be diminished. The best proportion for the height is from one-fifth to one-fourth of the base, according to the extent of the pediment, and the character of the body it covers. The materials of the roof must also be attended to; for, if it be covered with tiles, it will be necessary to raise it more than one-quarter of the base, as was the custom of the ancients in their Tuscan temples. The tympan is always on a line with the front of the frieze; and, when large, admits of various ornaments, as in the pediment to the western elevation of the temple of Minerva at Athens.

OF BALLUSTRADES.

Ballustrades are sometimes of real use in buildings; and at other times they are only ornamental. Such as are intended for use, as when they are employed in stair-cases, before windows, or to inclose terraces, &c. must always be nearly of the same height; never exceeding three feet and a half, nor ever less than three. But those that are principally designed for ornament, as when they finish a building, should be proportioned to the architecture they accompany; and their height ought never to exceed four-fifths of the height of the entablature on which they are placed; nor should it ever be less than two-thirds thereof, without counting the zocholo, or plinth, the height of which must be sufficient to leave the whole ballustrade exposed to view.

The best proportion for ballustrades is to divide the whole given height into thirteen equal parts; eight of these for the height of the ballustre, three for the base, and two for the cornice or rail: or into fourteen (if it be required to make the ballustre less), giving eight parts to the ballustre, four to the base, and two to the rail. One of these parts may be called a module; and, being divided into nine minutes, may serve to determine the dimensions of the particular members.

In ballustrades, the distance between two ballustres should not exceed half the diameter of the ballustre measured in its thickest part, nor be less then one-third of it.

The breadth of the pedestals, when they are placed on columns or pilasters, is regulated by them; the dye never being made broader than the top of the shaft, nor much narrower; and, when there are neither columns nor pilasters on the front, the dye should not be much lower than a square, and seldom higher. On stairs, or any other inclined planes, the same proportions are to be observed as on horizontal ones.

OF NICHES AND STATUES

It has been the custom of every age to enrich different parts of buildings with representations of the human body. Thus the ancients adorned their temples, baths, theatres, &c. with statues of their deities, heroes, and legislators. The moderns still preserve the same custom, placing in their churches, palaces, &c. statues of illustrious persons, and even groups composed of various figures, representing occurrences collected from history, fables, &c. Sometimes these statues or groups are detached, raised on pedestals, and placed contiguous to the walls of a building, or in the middle of a room, court, or public square. But they are most frequently placed in cavities made in the walls, called niches. Of these there are two sorts, the one formed like an arch in its elevation, and semi-circular or semi-elliptical in its plan; the other is a parallelogram

lelogram both in its plan and elevation. The proportion of both these niches depends on the characters of the statues, or the general form of the groups placed in them. The lowest are at least a double square in height; and the highest never exceed two and a half of their breadth.

With regard to the manner of decorating them, when they are alone in a composition, they are generally inclosed in a pannel, formed and proportioned like the aperture of a window, and adorned in the same manner. In this case the niche is carried quite down to the bottom; but on the sides and at the top, a small space is left between the niche and the architrave of the pannel. And when niches are intermixed with windows, they may be adorned in the same manner with the windows, provided the ornaments be of the same figure and dimensions with those of the windows.

The size of the statue depends on the dimensions of the niches. They should neither be so large as to have the appearance of being rammed into the niches, as in Santa Maria Majora at Rome; nor so narrow as to seem lost in them, as in the Pantheon. The distance between the outline of the statue and side of the niche should never be less than one-third of a head, nor more than one half, whether the niche be square or arched; and, when it is square, the distance from the top of the head to the ceiling of the niche should not be greater than the distance on the sides. Statues are generally raised on a plinth, the height of which may be from one-third to one-half of a head; and sometimes, where the niches are large, the statues may be raised on small pedestals. The character of the statue should always correspond with the character of the architecture with which it is surrounded. Thus, if the order be Doric, Hercules, Jupiter, Mars, Æsculapius, and all male statues, representing beings of a robust and grave nature, may be introduced; if Ionic, then Apollo, Bacchus, &c. and, if Corinthian, Venus, Flora, and others of a delicate nature, should be employed.

OF CHIMNEYS AND CHIMNEY PIECES.

Chimney-pieces are either made of stone, of marble, or of a mixture of these; also of wood, scagliola, or-moulu, or some other unfragile substances. Those of marble are most costly, but they are also most elegant, and the only ones used in highly-finished apartments; where they are seen either of white or variagated marbles, sometimes inlaid and decorated with the materials just mentioned. All their ornaments, figures, or profiles, are to be made of the pure white sort; but their friezes, tablets, pannals, shafts of columns, and other plain parts, may be of party coloured marbles, such as the yellow of Sienna, the Brocatello of Spain, the Diaspers of Sicily, and many other modern as well as antique marbles, almost always to be had in London. Festoons of flowers, trophies and foliages, frets, and other such decorations, cut in white statuary-marble, and fixed upon grounds of these, have certainly a very delicate effect. But there should never be above two or at most three, different sorts of colours in the same chimney-piece, all brilliant, and harmonizing with each other. Neither the Italians nor French have excelled in compositions of this kind; but Britain, possessed of many able sculptors at different times, has occasionally surpassed all other nations, both in taste of design and workmanship.

The size of the chimney must be regulated by the dimensions of the room where it is placed. In the smallest apartments, the breadth of the aperture should never be less than three feet, or three feet six inches. In rooms from twenty to twenty-four feet square, or of equal superficial dimensions, it may be from four to four and a half feet broad; in those of twenty-four to twenty-seven, from four and a half to five; and, in such as exceed these dimensions, the aperture may even be extended to five and a half to six feet. The chimney should always be situated so as to be immediately seen by those who enter the room. The middle of the partition-wall is the most proper place in halls, saloons, and other rooms of passage; but in drawing-rooms, dressing-rooms, and the like, the middle of the back wall is the best situation. In bed rooms, the chimney is always in the middle of one of the partition-walls; and in closets and other very small places, to save room it is put in a corner. Where ever two chimneys are used in the same room, they should be placed either directly facing each other, if in different walls, or at equal distances from the centre of the wall in which they both are.

The proportion of the apertures of chimney-pieces of a moderate size is generally a perfect square; in small ones it is a trifle higher, and, in large ones, a trifle lower. In designing them, regard must be had to the nature of the place where they are to be employed. Such as are intended for halls, saloons, guard-rooms, galleries, and other large places, must be composed of large parts, few in number, of distinct and simple forms, and having a bold relief; but chimney-pieces for drawing-rooms dressing-rooms, &c. may be of a more delicate and complicated nature.

OF CEILINGS.

Ceilings are either flat, or coved in different manners. The simplest of the flat kind are those adorned with large compartments, surrounded with one or several mouldings, or borders, either let into the ceiling, or projecting beyond its surface; and when the mouldings that form the compartments are enriched, and some of the compartments adorned with well executed ornaments, such ceilings have a good effect. The ornaments and mouldings do not require a bold relief: but, being near the eye they must be finished with taste and neatness. The principal effect of all flat ceilings depends very much upon the richness and beauty of the cornice.

Coved

Coved ceilings are more expensive: but they are likewise more beautiful. They are used promiscuously in large and small rooms, and occupy from one-fifth to one-third of the height of the room. If the room be low in proportion to its breadth, the cove must likewise be low; and when it is high the cove must be so likewise, by which means the excess of the height will be rendered less perceptible. But, where the architect is at liberty to proportion the height of the room to its superficial dimensions, the most eligible proportion for the cove is one-fourth of the whole height. The figure of the cove is commonly either a quadrant of a circle or of an ellipsis, taking its rise a little above the cornice, and finishing at the border round the great pannel in the centre. The border projects somewhat beyond the coves on the outside; and, on the side towards the pannel, it is generally made of sufficient depth to admit the ornaments of an architrave. In Britain, circular rooms are not much in use; but they are very beautiful. Their height must be the same with that of square rooms; their ceilings may be flat: but they are handsomer when coved, or of a concave form.

When the profiles of rooms are gilt, the ceilings ought likewise to be gilt. The usual method is to gild all the ornaments, and to leave all the grounds white, pearl colour, light blue, or of any other tint proper to set off the gilding to advantage. Historical and other paintings are often used with good effect in the centre and angular compartments of large ceilings; and since the rapid and elegant improvements in plaster and stucco have been introduced, a late invention of painted silk and sattin in various ornaments, from antiques, have likewise been adopted, to adorn the profiles or walls of rooms. These are inclosed in pannels, pilasters, and tablets, according to their destination; and, when they have suitable gilt mouldings, they produce a very gay and splendid effect.

Among the greatest ornaments and completest models of modern architecture in Great Britain, Somerset-place in the Strand, and St. Paul's cathedral rank the first; and, as they might justly be considered national specimens of the "sublime and beautiful in building," we think it incumbent upon us to describe them here.

Somerset-place is erected on the scite of old Somerset-house, on the banks of the Thames. The front towards the Strand is but little more than one hundred and thirty feet long; and all that an architect could do in so small a compass, and all that he seems to have wished, was to produce an object that should indicate something more considerable within, and excite the spectator's curiosity to a nearer examination of the whole fabric, of which this is only one external part. His style, in consequence, is bold, simple, and regular. It is an attempt to unite the chastity and order of the Venetian masters with the majestic grandeur of the Roman. The parts are few, large, and distinct; the transitions sudden, and strongly marked. No breaks are seen in the general course of the plan, and little movement in the outline of the elevation; whence the whole structure has acquired an air of consequence, which few artists, in so narrow a limit, would have given it. This front consists of a rustic basement, supporting columns of the Corinthian order, crowned in the centre with an attic, and at the extremities with a ballustrade. The basement is composed of nine large arches, the three centre ones of which, being open, form the principal entrance; the others are filled with Doric windows, ornamented with pilasters, entablatures, and pediments. The key-stones of the arches are adorned with nine masks or heads, finely carved in alto relievo, descriptive of the ocean, and the following principal rivers of England: Thames, Severn, Humber, Mersey, Tyne, Medway, Dee, and Tweed; and to these masks are added various emblematical devices, denoting the respective properties and peculiarities of each; and, as they are executed with much taste and skill, they merit a particular description.

Ocean is placed in the centre, and is represented by the venerable head of an old man, whose flowing beard resembles waves, which are filled with various kinds of fish. A crescent is on his forehead, denoting the influence of the moon on its waters, and his temples are adorned with crowns, tridents, and other marks of royalty. Thames is on the right of Ocean: a majestic mask, crowned with billing swans, and luxuriant garlands of fruits and flowers. The hair and beard are nicely dressed and plaited, and the features are expressive of good sense, good humour, and every species of urban perfection. Humber is the next in order to the right of the centre; a striking contrast to the Thames. It is an athletic hardy countenance, with the beard and hair disordered by the fury of tempests. The cheeks and eyes are swollen with rage, the mouth is open, and every feature distorted, expressive of the boisterous intractable character of that river. Next are the Mersey and the Dee; one crowned with garlands of oak, the other with reeds, and divers aquatic productions. The four first of these are executed by Mr. Wilton, and the last by Signor Carlini.

The masks which decorate the arches on the left side, are, first, the Medway; a head similar to that of the Thames, but expressive of less urbanity, more negligently dressed, and bearing for emblems the prow of a ship of war, with festoons of hops, and such fruits as enrich its banks. Tweed is next in order; a rustic mask, with lank hair, a rough beard, and other marks of rural simplicity; yet hath the ingenious sculptor artfully given it a character of sagacity, valour, fortitude and strength. It is crowned with a garland of roses and thistles. These are by Mr. Wilton. Tyne and Severn are the remaining two. Tyne is a head-dress artfully composed of salmon, intermixed with kelp, and other sea-weeds. Severn is a similar head-dress, compo-

 sed

sed of sedges and cornucopias, from whence flow abundant streams of water, wit i lampreys and other fish that abound in that river. These are by Signor Carlini.

The floor consists of a principal, and a mezzanine; and before the windows of the building is a ballustrade. They are besides ornamented with Ionic pilasters, entablatures, and pediments; and the three central ones have large tablets, covering the architrave and frieze, on which appear medallions of the king, the queen, and the prince of Wales, supported by lions, and ornamented with garlands of myrtle, oak, and laurel. The windows of the mezzanine floor are only surrounded with architraves. The attic consists of three divisions, separated by Colossal figures, placed above each of the columns. The figures represent four venerable statesmen, in senatorial robes, each having on his head a cap of liberty, and in their hands they bear the emblems of strength and power, derived from unanimity, and maintained by justice, prudence, moderation, and valour. The attic is crowned with a group, consisting of the imperial arms of the kingdoms, one side of which is supported by the Genius of England, and the other by Fame, sounding her trumpet.

The front of this building, towards the principal court, is considerably longer than that towards the Strand, being near two hundred feet in extent. The centre of this front is also better distinguished than that towards the Strand; it exhibits a plainness and repose, whereon the eye may rest with pleasure, as on a principal. It is composed of a *corps de logis*, with two projecting wings; the style of decoration is, however, nearly the same; the principal variation consisting in the doors, windows, or smaller parts, which are of other forms, and of different dimensions. The five masks on the key-stones of the arches represent tutelar deities of the place, executed by Mr. Nollekens. Near this front are two sunken courts, surrounded with elegant arcades, serving to give light to the basement story of the royal academy, the royal society, and the rooms wherein are deposited the national records. In the middle of each of these courts is a reservoir of water, for the purpose of serving the apartments below, and to be ready in case of fire. They are supplied from the New River.

The buildings towards the court form three sides of a square; the style of architecture, and the decorations of the wings, differing in form and dimensions. The statues of the attic represent America breathing defiance, with the three other quarters of the globe loaded with fruits and other tributary treasures; and these are crowned with the British arms on a cartel, surrounded with sea-weeds, supported by Tritons armed with tridents, and holding nets containing fish and other maritime productions.

This truly magnificent building is constructed for the purpose of transacting the business of several of His Majesty's public offices, viz. the privy-seal and signet, the navy, navy-pay, victualling, sick and wounded, ordnance, stamp, lottery, salt tax, hackney-coach, hawkers and pedlars, the surveyor-general of the crown-lands, the duchies of Cornwall and Lancaster, the two auditors of Imprests, the pipe, comptroller of pipe, clerk of the estreats, and treasurers's remembrancers. Here are houses for the treasurer, the pay-master, and six commissioners of the navy. Also for three commissioners of the victualling and their secretary; for one commissioner of the stamps, and one of the sick and wounded; and other apartments for inferior officers.

That part of the edifice which fronts the Strand is in possession of the royal society, the antiquarian society, and the royal academy of artists; and here the annual exhibition of paintings and sculpture is held. These respectable bodies are also accommodated with halls and apartments for their libraries, models, &c. with rooms for their officers, and every other requisite which their national consequence could demand from an enlightened and liberal government.

The buildings which contain the above-mentioned public offices form the principal court. They are grand, elegant, of great extent, and strikingly indicate an exertion of great inventive faculties in the architect, Sir William Chambers; while the general disposition affords a pleasing satisfaction. The front towards the Thames is truly magnificent; it is finished with a noble terrace, with a bullustrade towards the river, and an extensive gravelway for carriages to go all round the external fronts of the whole building.

The next noble structure, which does honour to the national character, as well as to the cause of religion, is the cathedral church of St. Paul. This amazing edifice is situated upon a rising ground, between the entrances of Cheapside and Ludgate-street, in the very centre of the city of London, and upon the scite of the old Cathedral, which was burnt to the ground in the general conflagration of 1666. Sir Christopher Wren was the architect; and he was desired to prepare the plan of a new fabric, that should excel every building in the universe for magnificence and splendour. To give effect to the execution of so grand a design, the chamber of London was made an office for the receipt of contributions to defray the expences; into which, in ten years only, was paid the sum of £126,000. Charles II. generously gave a thousand pounds a-year out of his privy-purse, besides a duty on coals, which produced £5000 a year, over and above all other grants in its favour. Sir Christopher prepared a design well studied and truly magnificent, conformable to the best style of the Greek and Roman archecture which all approved except the bishops, who thought it not sufficiently laid out in the cathedral fashion. The design was therefore varied in many respects,

respects, until the plan of the present mighty structure, which is in the form of a long cross, was unanimously approved; soon after which the building was put in hand, and the first stone was laid by Sir Christopher himself, on the 21st of June, 1675.

The foundations being laid, Portland stone was chosen to complete the superstructure. The walls are wrought in rustic, and strengthened, as well as adorned, by two rows of double pilasters, one over the other; the lower of the Corinthian order, and the upper of the Composite. The spaces between the arches of the windows and the architrave of the lower order, are filled with a great variety of grand enrichments, as are also those above. The west front, towards Ludgate-street, has a most noble appearance, and is ornamented with a magnificent portico, a grand pediment, and two stately turrets. The ascent is by a beautiful flight of steps, of black marble, that extends the whole length of the portico, which is formed of twelve lofty Corinthian columns below, and eight of the Composite order above: these are all coupled and fluted. The upper series support a noble pediment, crowned with its acroteria, in which is a beautiful representation, in bass-relief, of the conversion of St. Paul, executed in a very masterly manner. The magnificent figure of St. Paul on the apex of the pediment, with St. Peter on his right hand, and St. James on his left, have also a fine effect. The four evangelists, with their proper emblems, on the front of the towers, are judiciously disposed and well executed. St. Matthew is distinguished by an angel, St. Mark by a lion, St. Luke by an ox, and St. John by an eagle. In the area of this front, on a pedestal of excellent workmanship, is a statue of Queen Ann, formed of white marble, with proper decorations. The figures on the base represent Britannia with her spear, Gallia with a crown, Hibernia with a harp, and America with a bow. On ascending the steps, we approach the interior of the church by three doors, ornamented on the top with bass-relief: the middle door, which is by far the largest, is cased with white marble, and over it is a fine piece of basso-relievo, in which St. Paul is represented preaching to the Bereans, To the north portico there is an ascent by seventeen circular steps of black marble; and it has a dome, supported by six large fluted columns of the Corinthian order, forty-eight inches in diameter. Beneath the upper part of its dome, is a large and well-proportioned urn, finely ornamented with festoons, and over it a pediment, supported by pilasters in the walls, in the front of which is carved the royal arms, with the regalia, supported by angels; and on the top, at proper distances, are placed the statues of five of the apostles. The south portico answers in uniformity to the north, and has a dome supported by six beautiful Corinthian columns; but, as the ground is considerably lower on this than on the other side of the church, the ascent is by a flight of twenty-five steps. This portico has also a pediment above, in which is a phœnix rising out of the flames, with the motto *Resurgam*, underneath it, as being emblamatical of the present cathedrals rising out of the fire of London. On this side of the building are also five statues, which take their situation from that of St. Andrew, on the apex of the last-mentioned pediment. At the east end of the church is a sweep, or circular projection, for the altar, finely ornamented with a great variety of the orders, and decorated with sculpture.

The dome, that great master-piece of classical architecture, which rises in the centre of the whole fabric, appears exceedingly grand; twenty-five feet above the roof of the church, is a circular range of thirty-two columns, with niches placed exactly against others within; these are terminated by their entablature, which supports a handsome gallery, adorned with a ballustrade, above these columns is a range of pilasters, with windows between, and from the entablature of those the diameter decreases very considerably, and two feet above that it is again contracted. From this part the external sweep of the dome begins, and the arches meet at fifty-two feet above; on the top of the dome is an elegant balcony, and from its centre rises the lantern, adorned with Corinthian columns; and the whole is terminated by a ball, on which stands a cross, both of which are elegantly gilt. When these parts are viewed from below, they greatly deceive the eye of the beholder, on account of their great height, as they appear exceedingly small in comparison with their real size, which is amazingly large.

This extensive fabric is surrounded, at a proper distance, by a dwarf stone wall, on which is placed the most magnificent ballustrade of cast iron, perhaps in the universe, of about five feet six inches in height, exclusive of the wall. In this enclosure are seven beautiful iron gates, which, together with the ballustrades, in number about 2500, weigh 200 tons and 81lb. which having cost 6d. per pound, the whole, with other charges, amounted to 11,202l. 6d. The total cost of the whole fabric, even in those cheap times, was 736,752l. 2s. 3¼d.

On entering at the western door, the mind is struck by the grandeur of the vista; an arcade supported by massy and lofty pillars on each side, divide the church into the body and two ailes, and the view is terminated by the upper extremity of the choir; though it is in some measure obstructed by the organ. The pillars are adorned with columns and pilasters of the Corinthian and Composite orders, and the arches of the roof are enriched with shields, festoons, chaplets, and other ornaments. Its dimensions are as follow:

THE PLAN, OR LENGTH AND BREADTH.

	Feet.
Whole length of the church and porch - -	500
Whole length of the cross - - - - - - -	250

Breadth

	Feet.
Breadth of the front with the turrets - - -	180
Breadth of the front without the turrets - -	110
Breadth of the church and three naves - -	130
Breadth of the church and widest chapels -	180
Length of the porch within - - - - - -	50
Breadth of the porch within - - - - -	20
Length of the platea at the upper steps - -	100
Breadth of the nave at the door - - - -	40
Breath of the nave at the third pillar, and tribuna - - - - - - - - - - - -	40
Breadth of the side-ailes - - - - - - -	17
Distance between the pillars of the nave - -	25
Breadth of the same, single pillars - - -	10
Two right sides of the great pilasters of the cupola - - - - - - - - - - - -	25.35
Distance between the same pilasters - - -	40
Outward diameter of the cupola - - - -	145
Inward diameter of the same - - - - -	100
Breadth of the square by the cupola - - -	43
Length of the same - - - - - - - - -	328
From the door within to the cupola - - -	190
From the cupola to the end of the tribuna -	170
Breadth of each of the turrets - - - - -	35
Outward diameter of the lantern - - - -	18
Whole space upon which one pillar stands -	875
Whole space upon which all the pillars stand	7000
THE ELEVATION.	
From the ground without to the top of the cross - - - - - - - - - - - - -	340
The turrets - - - - - - - - - - -	222
To the top of the highest statues on the front	135
The first pillars of the Corinthian order - -	33
The breadth of the same - - - - - -	4
Their basis and pedestals - - - - - -	13
Their capital - - - - - - - - - - -	5
The architrave, frieze, and cornice - - -	10
The Composite pillars at St. Paul's - - -	25
The ornaments of the same pillars above and below - - - - - - - - - - - -	16
The ball in height - - - - - - - - -	8
The cross, pedestal, and base - - - - -	29
The triangle of the mezzo relievo, with its cornice - - - - - - - - - - - -	18
Width - - - - - - - - - - - - -	74
The basis of the cupola to the pedestals of the pillars - - - - - - - - - - -	38
The pillars of the cupola - - - - - - -	28
Their basis and pedestals - - - - - -	5
Their capitals, architrave, frieze and cornice	2
From the cornice to the outward slope of the cupola - - - - - - - - - - - -	40
The lantern from the cupola to the ball - -	50
The statues upon the front, with their pedestals - - - - - - - - - - - - -	15
The outward slope of the cupola - - - -	50
The cupola and lantern, from the cornice of the front to top of the cross - - - - -	240
The height of the niches in the front - - -	14
Width - - - - - - - - - - - - - -	5
The first windows in the front - - - -	13
Width - - - - - - - - - - - - - -	7

The extent of the ground-plot, on which the building stands, is two acres, sixteen perches, twenty-three yards, and one foot.

All the floor of the church and choir, to the altar, is paved with marble; the altar is paved with porphyry, polished, and laid in several geometrical figures. The vaulting of the roof is hemispherical, consisting of twenty-four cupolas, cut off semicircular, with segments to join to to the great arches one way, and the other way they are cut across with elliptical cylinders, to let in the upper lights of the nave; but in the aisles, the lesser cupolas are cut both ways in semicircular sections, and altogether produce a graceful geometrical effect, distinguished with circular wreaths, which is the horizontal section of the cupola. The arches and wreaths are of stone, carved; the spandrels between are of sound brick, invested with stucco of cockle-shell lime, which becomes as hard as Portland-stone; and which, having large planes between the stone-ribs, are capable of further ornaments of painting, if required. Besides these twenty-four cupolas, there is a half-cupola at the east; and the great cupola of 108 feet diameter in the middle of the crossing of the great ailes; it is extant out of the wall, and is illumined by the windows of the upper order, which strike down the light through the great colonnade that encircles the dome without, and serves for the butment of the dome, which is brick, of two bricks thick; but, as it rises every way five feet high, it has a course of excellent brick of eighteen inches long, bending through the whole thickness; and, to make it still more secure, it is surrounded with a vast chain of iron, strongly linked together at every ten feet; this chain is let into a channel cut into the bandage of Portland-stone, and defended from the weather by filling the groove with lead. Over the first cupola is raised another structure of a cone of bricks, so built as to support a stone lantern of an elegant figure, and ending in ornaments of copper, gilt; the whole church above the vaulting being covered with a substantial oaken roof and lead, so this cone is covered and hid out of sight by another cupola of timber and lead: between which and the cone are easy stairs, which ascend to the lantern. The contrivance here is astonishing. The light to these stairs is from the lantern above.

The inside of the dome is painted and richly decorated by Sir James Thornhill, who, in eight compartments, has represented the principal passages in the history of St. Paul's life, namely, his conversion; his punishing Elymas the sorcerer with blindness; his preaching at Athens; his curing the poor cripple at Lystra, and the reverence there paid him by the priests of Jupiter as a god; his conversion

sion of the gaoler; his preaching at Ephesus, and the burning the magic books in consequence of the miracles he there wrought; his trial before Agrippa; his shipwreck on the island of Melita, or Malta, and his miracle of the viper.

The highest or last stone, on the top of the lantern, was laid by the hands of Christopher Wren, the surveyor's son, in the year 1710. Thus was this mighty fabric, lofty enough to be discerned at sea eastward, at Windsor westward, in the space of thirty-five years, begun and finished by one architect, and under one bishop of London, Dr. Henry Compton. Whereas St. Peter's at Rome, the only edifice that can come in competition with it, continued in building 145 years, under twelve successive architects, assisted by the police and interests of the Roman see; attended by the best artists of the world in sculpture, statuary, painting, and mosaic work, and facilitated by the ready acquisition of marble from the neighbouring quarries of Tivoli.

This grand cathedral, thus finished, as an excellent author observes, "is undoubtedly one of the most magnificent modern buildings in Europe; all the parts of which it is composed are superlatively beautiful and noble. The north and south fronts in particular are very perfect pieces of architecture; neither ought the east to go without due applause. The two spires at the west end are in a finished taste; and the portico with the ascent, and the dome that rises in the centre of the whole, afford a very august and surprising prospect." In short, in surveying this stupendous monument of our country's genius, the imagination is filled with a lofty kind of admiration, which no building of less majesty and grandeur could possibly excite.

We might instance as beautiful specimens of the art the fragment of a palace at Whitehall, now used as a chapel, and justly deemed one of the noblest productions of that incomparable master, Inigo Jones; also, the interior of St. Stephens Church, Walbrook, by Sir Christopher Wren, deemed by foreigners a more splendid proof of his abilities than even St. Pauls itself.

BRIDGES.

Bridge, in *Architecture*, is a structure of Masonry, Carpentry, or iron-work, built over a canal, river, or valley, erected for the convenience of passing from one side to the other, and supported by arches or links, and these again supported by piers or butments.

Bridges generally form the continuation of a road or highway, or of a street; in the first case they are often built in a rude and cheap manner, and without attention to those principles which alone insure permanence and solidity; but when they form the entrance to or form the principal street of a large city, their construction is most generally attended with great expence, and a degree of elegance and durability is required in their formation, that calls for the utmost skill of the architect. Palladio, in this case, tells us, that bridges ought to have the same qualifications that are judged necessary in all other buildings, namely, that they should be convenient, beautiful, and lasting. The perfection of a bridge consists in its having a good foundation, which makes it lasting; an easy ascent, which makes it convenient; and a just proportion in its several parts, which renders it beautiful. In the erection of stone bridges, there are several requisites which demand our attention. In the first place, the butments not only receive the pressure of the arches, with which they are connected, but they must be capable of resisting in some measure the force of the whole combined. Hence the necessity of a solid foundation at the opposite sides of the river; without which all the arches will be subject to the least partial rents.

Bridges ought always to be constructed at right angles to the current, and the piers ought not to be larger than what is absolutely necessary for the support of the arches; for when they are constructed of an unnecessary thickness, it contracts the current of water, which it is well known will increase its velocity, and thereby render the foundation of each pier more liable to be undermined. Lastly, we are to decide on the number and figure of the arches, which are points of great consequence to the whole, in relation to its strength, usefulness, beauty, and economy.

We find a great difference of opinion among architects in the choice of arches; and even among mathematicians, who are unquestionably the best judges of the subject; for the strength and solidity of a bridge must depend on mathematical principles. Some have contended that semicircular arches ought in most cases to be preferred, because they press more perpendicularly on their piers, and in proportion to their number will diminish the pressure on the butments. Others have preferred elliptical arches, when they are to be large and but few in number; because the extensive radius of the semicircular arch would occasion the centre of the bridge to be so high as to render the passage of carriages exceedingly troublesome; an objection which is re-

moved completely in the elliptical form, its elevation being considerably below the semicircle; and Mr. Muller asserts, that the elliptical arch does not press against the piers with a greater force than a circular one; and being lighter, and constructed with less materials, will consequently be more lasting."

There are others, however, who prefer the Catenarian arch to all others, for the purpose of bridges. The celebrated Emerson, in his principles of mechanics, insists "that it is the strongest arch possible to be made, for supporting a great weight.' But the learned Dr. Hutton, late professor of the mathematics to the royal military academy, asserts, that the arch of equilibration is the only perfect one adapted to the principles of bridges. This arch, being in exact equilibrium in all its parts, and having no tendency to break in one part more than another, is therefore the safest and strongest. Every particular figure of the estrados, or upper side of the wall above an arch, requires a peculiar curve for the under side of the arch itself, to form an arch of equilibration; so that the incumbent pressure on every part may be proportional to the strength or resistance there. When the arch is equally thick throughout, a case that can hardly ever happen, then the Catenarian curve is an arch of equilibration, but in no other case; and therefore it is a great mistake in some authors to suppose that this curve is the best figure for arches in all cases, when in reality it commonly the worst.

TABLE FOR CONSTRUCTING THE CURVE OF EQUILIBRATION,

Value of K I	Value of I C	Value of K I	Value of I C	Value of K I	Value of I C
0	6.000	21	10.381	36	21.774
2	6.035	22	10.858	37	22.948
4	6.144	23	11.368	38	24.190
6	6.324	24	11.911	39	25.505
8	6.580	25	12.489	40	26.894
10	6.914	26	13 106	41	28.364
12	7.330	27	13.761	42	29.919
13	7.571	28	14.457	43	31.563
14	7.854	29	15.196	44	33 299
15	8.120	30	15.980	45	35.135
16	8.430	31	16.811	46	37.075
17	8.766	32	17.693	47	39.126
18	9.168	33	18.627	48	41.293
19	9.517	34	19.716	49	43.581
20	9.934	35	20.665	50	46.000

Explanation of the above Table.

Let *Figure* 1,—*Plate Bridge*, represent an arch of equilibration; in which suppose D K be 6, D Q be 40, and A Q 50; then the corresponding values of K I and I C are very readily found by the preceding table; thus, if K I be 30, then I C is 15·980.

Among all the arches, there is no one, except the mechanical curve of the arch of equilibration, that can admit of an horizontal line at top; yet this arch is of a form both graceful and convenient, and it may be made higher or lower at pleasure, with the same span or opening. All other arches require extrados that are curved, more or less, either upwards or downwards. Of these, the elliptical arch approaches the nearest to that of equilibration for equality of strength and convenience; and it is also the best form for most bridges, as it can be made of any height to the same span, its hanches being at the same time sufficiently elevated above the water, even when it is very flat at top. Elliptical arches also look bolder and lighter, are more uniformly strong, and much cheaper than most others, as they require less materials and labour. Of the other curves, the cycloidal arch is next in quality to the elliptical one, for those properties; and, lastly, the circle. As to the others, the parabola, hyperbola, and catenary, they are quite inadmissible in bridges that consist of several arches; but may, in some cases, be employed for a bridge of one single arch which may be intended to rise very high, as in such cases they are not much loaded at the hanches.

The dimensions of the piers for bridges must be determined by those of the arch. According to Palladio, they should never exceed one-fourth, nor be less than one-sixth of its width. The plans of piers for bridges are generally drawn of an hexagonal form, having its two long sides parallel to each other; and at the ends are placed two short ones facing the course of the river at right angles to each other; though sometimes they are made semicircular facing the stream, in order to divide the water, that those things which are impetuously brought down the river, when they strike against them, may be thrown from the piers, and pass through the middle of the arch. Palladio assigns to the dimensions of key-stones, one-seventeenth part of the width of the arch, which judicious proportion we may safely venture to recommend. Of a bridge which that celebrated architect designed, he gives the following proportions: the river was 180 feet wide, which he divided into three arches, giving sixty feet to the centre arch, and to the other two, forty-eight feet each. The piers were twelve feet thick, or one-fifth part of the width of the middle arch, and a fourth-part of the smaller ones. The arches were a small portion less than a semicircle; and their key-stone one-seventeenth part of the opening of the middle arch, and one-fourteenth part of the other two. In an arch of twenty-four feet, Palladio makes the length of the key-stone about sixteen inches, which is considered as a very eligible size.

Bridges are generally constructed about thirty feet

feet wide; but in large ones near great towns, a banquette, or raised foot-path, is added on each side, for the convenience of passenges, from six to nine feet each, and raised about a foot above the middle or horse passage; the parapet walls are about eighteen inches thick, and four feet high; they generally project from the bridge with a cornice underneath. In good bridges, to build the parapet but a little part of its height close or solid, and upon that a balustrade of stone or iron, has an elegant effect. The ends of bridges open from the middle of the two large arches with two wings, making an angle of forty-five degrees with the rest, in order to make their entrance more free; these wings are supported by a continuation of the arches; that under each wing being smaller than the rest; but the wings of bridges are generally supported by the solid abutments alone.

Autumn is considered the most proper season for laying the foundations of a bridge; because, then the waters are the lowest, and the weather most favourable for such operations.

The most simple method of laying the foundatiens, and raising the piers up to the water mark, is to turn the river out of its course above the place of the bridge, into a new channel cut for it near the place where it makes an elbow or turn; or by raising an enclosure to keep off the water, by driving a double row of stakes very close to one another, with their tops above the surface of the water, like a trench. Hurdles are then put within this double row of stakes, and the side of the row which is next to the intended pier, must be closed up and the hollow between the two rows filled with rushes and mud, rammed together so hard, that water cannot possibly get through. Then the mud, sand, &c. within the inclosure, must be dug out until a solid foundation appears; when this cannot be found, a foundation made of wooden piles charred at their ends, are driven in as close as possible. Many eminent architects have made a continued foundation of the whole length of the bridge, and not merely under each pier. To effect this, one part of the river was excluded at one part, then another, and so joining the whole together by degrees; for it would be impossible to repel the whole force of the water at once. If the expense of a continued foundation should be thought too great, a separate foundation may be formed for each particular pier, in the form of a ship, with an angle in the head and another in the stern, lying directly even with the current of water, that the force of the water may be broken by the angles. Palladio, whose opinion ought generally to be respected; says "To lay the foundations of pilastars, if the bed of the river be stone or gravel-stone, you have the foundation without any trouble; but, in case the bottom be quicksand, or gravel, you must dig therein till you come to solid or firm ground; or, if that should be found too laborious or impracticable, you must dig moderately deep in the sand, or gravel, and then you must trust in oaken piles, which will reach the solid or firm ground, with the iron by which their points are to be armed. A part only of the bed of the river must be inclosed from the water, and then we are to build there; that the other part being left open, the water may have its free current; and so go from part to part. When a river is deep and destitute of a natural good bed, a foundation may be formed by driving a double row of piles, and filling them in between with close materials, and afterwards pumping out the water, and driving other piles within them. When a river is but moderately deep, and has a natural good foundation in its bed, capable of supporting a heavy pier; then a strong oaken frame is to be formed, which is to be buoyed up with boats; on this frame is laid a thick stratum or layer of stone, cramped together with iron, and joined with strong terrace mortar, the whole of which is to be let gently down to the bed of the river, in the place intended for the pier. Lastly when a bridge is to be built across a fordable river or a canal, and where there is a suitable place for turning the course of the water, either by a wooden fence placed in a sloping direction across the river, or by a channel sunk on one side of the bed of the river; then a dam must be made entirely across the river with the piles, and sufficiently wide to form the piers in; and the ground dug until a proper foundation appears, and then the piers may be raised all together above low water mark, and the water turned again into its original channels.

The ingenious Mr. Robert Semple laid the foundation of Essex-bridge in Dublin, in a very deep and rapid stream, in the year 1753, by the following method: round the place where the intended pier was to be built, two rows of strong piles were driven, about thirty inches distance from each other, and which were left at low-water mark. These piles were lined with planks, within which was rammed a quantity of clay, and thereby the external wall of the coffer dam formed. Within this wall were driven a row of piles at about the same distances, and dovetailed at their edges so as to receive each other, and which formed the extremities of the plan of the piers at the level of the bed of the river. After having dug to a fine stratum of sand about four feet lower, within these were a great number of other piles driven as deep as they could possibly be made to penetrate. The intervals of these piles were filled up and in order to produce a solid foundation, the first course was laid with mortar made up of roach-lime and sharp gravel, and on this, large flat stones were rammed to about a foot thick. On this first course was laid a thick coat of dry lime and gravel of the same quality, on which was again laid stones, and the mortar as at first; and so on alternately until arrived a perfect level with the piles. Three beams stretching

stretching the whole length of the pier, from sterling to sterling, were fastened down to the end of these piles, and their intervals filled up with masonry. On this platform, which was four feet six inches under low water mark, was laid the first course of stones for the pier, cramped together, and jointed with terrace mortar as usual; courses of stones were laid in this manner until arrived to a level with the water at ebb tide. The following method of laying the foundations of wharfs, piers, &c. is the invention of S. Bentham, esq. engineer of His Majesty's navy, and is guaranteed to him by letters patent, dated April 2, 1811; and which he describes as follows;

"I Samuel Bentham do hereby declare that the nature of my said invention, and in what manner the same is to be performed, is described by the drawings and referances hereunto annexed (*See Plate* I.) and the following description thereof, that is to say, to whatever depth the foundation of any structure is to be laid, under water or ground.

First I combine together above ground or above water, either over the place into which the foundation is to be forced, or elsewhere, stone or brick, or other artificially-composed materials, (with or without the introduction of wood or iron in the bottom, or for ties, as occasion may require,) into sometimes a number of distinct masses, and sometimes into one entire mass, which when put where they are, or it is to remain, shall constitute the foundation or lower part of any structure, together with more or less, or even the whole of the structure.

Secondly. I place those masses, or this mass, in their or its required situation, without the need of clearing away the water or ground to the depth of which they or it are or is to be laid, and in case of works under water, without the use of any cassion or dam, composed of wood or other materials, to inclose the work while building, conveying to the spot where it is to be deposited or depositing*.

Thirdly. I press the foundation masses or mass into the ground, either in its natural or in its artificially prepared state, whether under water or not with a degree of pressure, such as shall be deemed sufficient to prevent the farther injurious yielding of the ground when the superstructure shall be built up and be applied to use, and in giving this pressure previously to the proceeding with that part of the superstructure in regard to which any further sinking of the foundation would be injurious*. As to the formation of these masses, they may be either solid or hollow; or though hollow at first, for the convenience of floating; or otherwise removing them from place to place, or of depositing them, they may afterwards be more or less filled up. The exterior may be of one material, for lightness or for appearance sake, and the interior, for cheapness or for strength, of some different material, as, for instance, the mass may be first formed of a thin bottom, and then walls of brick, for the sake of lightness; the walls may afterwards be thickened, or the interior be intirely filled in with stone, with bricks, or with other artificially composed materials. Wood and iron may be employed as ties, as well as for beams, rafters, or any part of the superstructure of these masses, as is usual in building of which the walls are of masonry or brickwork.

The masses may be of any size or shape, from the depth, supposing them solid, of only a few bricks, and of the horizontal dimensions of a square of nine inches, (being the length of an ordinary brick,) or even less, to the size and shape, if hollow, adapted to contain the largest ship, or even several ships at a time, so as to form in one mass a dock or lock, or any other more extensive work.

As then the particulars of these masses may vary so much, the selection, in the instance of each particular work, of the most suitable form, material, and mode of proceeding, must consequently be left to the engineer, architect, mason, bricklayer, or other workman, to whom the management of the work may be intrusted; I proceed to specify, in the way of example, some particular shapes and dimensions of the masses, and some of the modes which may be employed for the conveying them to their places, depositing them, and pressing them down, which shall be metable * to some works of considerable importance and variety, so that a skilful engineer, architect, mason, or bricklayer, assisted in regard to the management of the masses that are to float by some one conversant in the management of floating bodies, may be enabled, by the consideration of these examples, to vary the construction of the masses, and the mode of proceeding in the use of them, according to the nature of the particular work he has to carry on, and according to the circumstances under which it is to be executed. Supposing that in a situation where at low water the depth of the water is twenty-four feet, and consequently where a ship of the line may at all times lie afloat, and where the ground is of such a nature as that within a depth of from five to ten feet from its surface is deemed incapable of bearing a solid wall with the weight of the several articles that may come to be deposited upon it, it be required to construct a wharf-wall, it may be proceeded with, according to my mode, as follows.

First let it be ascertained, by means of a probe or otherwise, to what depth, by a known weight pressing upon a base of known superficial extent, the ground in the scite of the proposed wall will be penetrated. Let the spot in question be then levell-ed

* Compared with the office copy.

* Stands so in the office copy.

ed where requisite, by means of an engine for digging under water, or otherwise; and if in the intended line of wall the evenness of the ground be interrupted by any matter too large to be removed, such, for instance, as portions of an old ship, let the ground in such parts be raised somewhat above the most prominent obstacles, by depositing stones, shingles, gravel, or other such materials, with a mixture, where convenient, of sea-weed, and with the addition of some lime, or other cement, if it be thought requisite to cement these materials together. Secondly, let hollow masses, twenty-one feet square at their base, with perpendicular sides, be prepared on a platform, in a situation where the tide, at the time of high water, rises sixteen feet above the platform. Let them be built of brick, cemented with Roman cement bottom and sides, so as to be water-tight, of the form and dimensions shewn by *Figure* 1, up to the height of twenty feet, letting in water on the rise of the tide, by means of a syphon or otherwise, to prevent their floating and running out the water by the same means as the tide falls. Thirdly, let the masses, when so far built, remain a short time on the platform, a week or more, so that the cement may indurate. Then let the water be drawn or pumped out of them, so that by their buoyancy they may float off the platform. Then having passed ropes or chains round them and under them, and having put up a pole in each corner, for the more convenient managing them when afloat, let them be taken immediately over the spot where they are to be deposited, or previously to some other place, where, on account of smoother water, or better protection, or on other accounts, they may lie more conveniently. And let them be built up to the height of thirty-five feet, beginning as soon as the buoyancy will admit of it to thicken and strengthen the bottom and lower part of the sides with additional brick-work, and filling in shingle, rubble, or other materials, mixing them with mortar or lime, so that these materials may indurate, and give strength to the bottom.

Fourthly. Having floated one of the masses as exactly as possible over the spot on which it is to be deposited, let water into it by means of a syphon, or otherwise, so that it may sink to the ground; then there will remain perhaps about eight or ten feet above water at the time of low water.

Fifthly. Having prepared a vessel laden so as that the total weight of the vessel and lading shall be somewhat more than the supposed weight of the additional superstructure, which will rest upon one mass, together with that of the heavy articles which the wall when finished may be supposed liable to bear, let this vessel be brought over the mass at the time of high water, and be placed so as to ground upon the mass when the water falls, having previously, according to the shape of the bottom of the vessel, made some preparation, by laying timbers on the mass, or otherwise, to cause the pressure to be sufficiently distributed over the surface of the mass, and observing, in case the mass should have rested out of the level, to place the vessel so as to press most on the highest side of the mass. By the time of low water, the vessel having rested entirely on the mass, unsupported by the water, the mass will have been pressed down more or less; and if it be materially out of the perpendicular, or other direction more desirable, let the vessel be removed during another high water to another part of the mass, so as to bring it into the proper direction; and let this operation be repeated until the position of the mass is corrected. If, however, from some unfavourable accident or otherwise the mass should not by these means be brought into the required situation, let the water during the recess of the tide be pumped out of the mass, so that it may be made to float again, which may be easily done, unless the bed on which it rests be such as to exclude the water from insinuating itself under the bottom, and let the bed itself be raised or levelled in any required part, so that on depositing and pressing the mass again it may rest in the desired situation. In the same manner let the other masses be brought over and deposited in their respective places. For the more easy adjustment of one mass in a line with the others, an indenture may be formed on the side of one mass, and a corresponding projection in the contiguous side of the other mass; or a perpendicular groove may be formed on the sides of each mass, corresponding with similar grooves in the sides of the contiguous masses, into which grooves, pieces of timber, in the form of folding wedges, may be inserted during the time of placing one mass against the other; after which the timbers may easily be taken out, and the spaces they occupied, as well as the joints or intervals between the contiguous masses, may be filled up with brick-work and grout, rubble-work, or other materials.

The data, dimensions, and materials described in this example being given only as the illustration of the general method, it is not meant as being essential to the execution of the wharf-wall upon my plan that the mode as above described should be minutely followed, but on the contrary, in my mode, work for a similar purpose may be executed in any depth of water, on any soil, of any dimensions, and of any materials, such as brick, stone of any kind, natural or artificial, or of any mixture of the smaller stones, such as shingle or gravel, artificially combined together with Roman cement, mortar, or other indurating material, taking care in each instance to calculate the weight of the materials of each intended mass previously to its construction, as also the quantity of water it will displace; so that by duly proportioning the thickness of the bottom and walls to the quantity of water the mass will displace, its buoyancy may be insured, taking care that the work be executed so as to be water-tight.

L When

When the masses forming component parts of the foundation have been deposited and pressed with the requisite pressure into their places, which pressure may be applied either gradually or suddenly, and be made to continue a longer or shorter time, according to the nature of the soil, the completion of the superstructure of the wall may be effected either by continuing these masses up distinctly, without bonding the work of one with that of the other, so that in case of any unprovided-for occurrence, one mass may be at liberty to settle farther without the other, or the work may be carried up in the usual way, bonding that over one mass with that over the adjacent one, so as to unite the whole together, and thereby the better ensure against any partial settling from partial causes. Or if it should be thought more advisable, with the view to avoid the delay of tide-work, or for any other reason, hollow masses may be prepared, of a height to reach from the top of the foundation masses, up, in some cases, as high as the wall is required to be carried; and these masses may be deposited upon the foundation ones, so as to complete the work up to its height, taking advantage of the recess of the tide to deposit a layer of mortar, or other cement, upon the upper surface of the lower mass, so as to receive the lower surface of the upper one, and this either so that each of these upper masses should coincide in dimensions, and rest exactly over one of the lower ones, or so as to extend over two or more of the foundation masses to form bond. The masses, whether under or upper ones, may either have their walls thickened after they are deposited, or they may be entirely filled up, or they may be made to serve for cellars or store rooms, or other useful purposes, having been prepared of suitable forms and dimensions for any such purpose that may have been in view. In the case of forming a mole or pier, with a view to its acting as a break-water to the waves of the sea, while at the same time it is desired that the tide or current should pass with as little interruption as possible, instead of forming an entire pier of masonry for such a purpose, or by throwing down stones, or materials of any kind, to form a mound, which would totally interrupt the passage of the current below, as well as oppose the violence of the waves above, two or more rows of distinct masses might be deposited in the direction of the intended break-water, leaving in each row of masses an interval between mass and mass for the free passage of the tide or current, but placing the masses of the interior row opposite to the intervals of the exterior row, so that the whole together should form a complete impediment to the direct action of the waves, yet allowing the tide or current to pass below between the masses even in a contrary direction. Supposing in this case the masses to be cylindrical, say fifty feet diameter, the interval between mass and mass in the row also fifty feet, then, by two such rows of masses, those of one row not more than twenty-five or thirty feet distant from those of the other row, the impediment thereby afforded to the waves, whether coming at right angles or oblique to the direction of such break-water, would in most cases be sufficient for the purpose of insuring smooth water within the space protected by those masses, while the passage of the tide or current would in no part of the pier be diminished more than half. But with the view to the affording a more complete impediment to the action of the waves, and at the same time a still less impediment to the course of the tide or current, masses might be constructed and deposited of a form suited to serve as foundation masses in the manner of the piers of a bridge: and superincumbent masses, prepared of a form suited to the extending from one foundation mass to the other, might be deposited, resting each end upon a foundation mass, forming altogether as it were a bridge, but differing from an ordinary bridge, inasmuch as with a view to the not opposing the under surface of the superincumbent mass to the violence of the waves, and to the affording as complete a protection during low water as at other times, the lower part of the continuous structure should be kept as low as to be always under water, even during low water.

These superincumbent masses having been made in the first instance hollow, with a view to the floating them to the others, on which they are to be deposited, if it should not be deemed necessary afterwards to fill them up, to afford greater strength or weight, might be formed with sloping sides towards the side exposed to the violent action of the sea, but with perpendicular sides towards the still water, and might be made to afford wharfage, and a great quantity of inclosed space, applicable to various useful purposes.

Supposing it be desired to build a bridge where the ground on which the piers are to stand has been found, by probing as well as boring, to be of an uniform tenacity, equally yielding, or when it can be made so by the deposit of any materials, let the foundation of each pier, with more or less of the superstructure, at least so much as to reach above low water, be of one single mass, and let it be floated, deposited, and pressed in the same manner as is described in regard to the wharf wall. Should the ground be of unequal degrees of firmness, or if on any other account it should be advisable that the foundation of each pier, with more or less of its superstructure, should be formed of any greater number of distinct masses, either contiguous to, or more or less distinct from one another, let each pier be proceeded with in distinct masses, as in the case of the wharf wall, but varying the forms of the masses, as may be most eligible, for the particular purpose of the pier. In cases where the bridge is to serve the purpose of a dam, with a sluice or a lock, between any of the piers, let a mass be constructed,

structed, of such form and dimensions as shall comprehend at least all the under-water part of the whole of the sluice, or other work requisite between the piers, together with a part, say half, of each of the piers, one on each side of the sluice. The bottom of each sluice or lock, may be in the form of an inverted arch, or otherwise; but as a mass so shaped would form only the bottom and two sides of the four requisite to form a cavity, by means of which the mass might be made buoyant, let the two other sides, or ends be formed, in a temporary manner, across the space between the half piers, one at each end, so as to keep out the water while such a mass should be building, or at least while it should be transporting to the place in which it would be deposited, and so that these temporary ends should afterwards be readily taken away. These temporary ends might conveniently and economically be formed of two floating dams, which being analagous in their use to floating dams employed instead of *gates* to keep the water out of docks, might be made on the same principles, or otherwise. And if all the arches of a bridge or dam were made of the same size, these two floating dams would serve not only as the temporary sides of the foundation masses for forming all the spaces between the piers, but they would afterwards serve to exclude the water from any of these spaces during the examination, the adjustment, or the repair of the sluices, or other work that might be requisite within these spaces. In a similar manner sluices or locks may be constructed in other situations than that of forming part of a bridge when the perpendicular wall, instead of forming halves of piers, may be made to join into walls of an embankment, or of a bason or canal. In like manner a dry dock, for the reception of one or more ships, of any size may be constructed, excepting that in this case the head of the dock would probably be composed of the same material as the sides, and only one floating dam, or other temporary boundary would be required for one of the ends of the mass, which might be the same dam or gates that would be requisite afterwards for the exclusion of the water from the dock when in use. For the forming an embankment in a situation where there is not, and where it is not required that there should be, a depth of water of more than eight or ten feet where the ground is uniform, and if not level, such as may easily be made so by a digging engine, or otherwise; and where cellar room, store-house room, and habitations are wanted as near as possible to the water; masses for an embankment, under such circumstances may be built of any suitable dimensions, in the mode exhibited by *Figure* 2; so as when deposited, to form at once fifty or one hundred feet or more of embankment, the expence of which would little exceed that of a building of the same size, constructed elsewhere, for the other purposes to which such a mass would be at the same time applicable. If it be required to stop the passage of a great body of water, as in the case of damming up a river, masses may be prepared, of the requisite depth, according to the situation they are respectively to be deposited in, and the bed may be prepared in a manner suited to their settling into the ground water-tight: and the sides being prepared with or without corresponding indentures, and with or without the interposition of some compressible or elastic substance they may be brought together and deposited at the time of still water, whether high or low water, as best suited to the purpose; and by placing them in a line somewhat curving towards the side from which the pressure will come, they may, as soon as a difference of level occasions a pressure, be forced by that pressure close together, and into the banks against which they are required to abut.

As to the general means of rendering masses for the before-mentioned purpose buoyant and strong, it is evident that, in point of buoyancy, nothing more is required, as before observed, than that they should be of a capacity in proportion to the weight of materials employed, so as to displace a quantity of water sufficiently great for its weight to exceed that of the materials used; so, in regard to the giving the requisite strength, the force with which water presses at different depths is well known, as are various means of using different materials to the best advantage to resist that force. But as the forming the sides as well as the bottoms of the masses in the first instance as light as possible, (however much they may be strengthened by additional materials afterwards) is a matter of more importance than in buildings of the usual kind, I have to observe, that one mode, of very extensive application for giving to such work great strength, with little weight, is the making the walls of the masses double, with cellular partitions, and the bottoms at first very thin, but strengthened by ribs of stone, or brick-work, which may be made in some cases, no thicker than the thickness of an ordinary brick, if the cement be strong, as shewn by *Figures* 2 and 4. Bottoms of masses so constructed, however great their superficial extent, may be advantageously built on platforms, not more than five or six feet below the level of high water, since by that means the work would be but little interrupted by the tide, and they might also be constructed on a platform composed of logs of timber floating on the water; and as soon as the sides of the masses were carried up sufficiently high to make them buoyant, the logs of timber might be drawn from under them. Or cellular bottoms may be formed, by preparing, first, small portions of this bottom, as represented by *Figure* 4, which portions being applied together, side by side, when floating in the water, and held by some temporary means close together, grout may be applied in the interstices at the place of juncture, so as to cement the portions together; after which they

they or other shaped compartments, may be raised upon, over the junctures so as to connect these several portions more firmly together, and the work may be proceeded with as if the whole bottom had been built ashore, and united together in one mass in the first instance. The masses for the above mentioned purposes being all of them structures in water, have been spoken of as hollow, a mode of forming them which seems in general preferable for water-works, on account of the facility of floating them about, and of raising or lowering them by the rise and fall of the tide. I have to observe, however, that according to my mode masses for such purposes might in many cases be made solid; and being formed over the spot on which they are to be deposited, they might be supported by tackles, or otherwise, during their construction, and be lowered down into the water as their structure is proceeded with; or they might be formed on land, and slid down on a kind of rail roads, or otherwise, in an inclined direction, one over the other, so as to form a progressive projection from the land into the sea; or, although formed elsewhere, they might be floated between vessels, or otherwise, to the place where they are to be deposited. They might also be made hollow, though without being water-tight, and be floated to their places, or even be built afloat, supported by buoyant bodies of various kinds, and in masses of various shapes, particularly in regard to cylindrical masses. A cylindrical vessel of wood, hooped together like a cask, might be applied on the inside of a cylindrical mass, by means of which interior support with or without the addition of some farther support, applied on the outsides of the mass, such a mass might be thus built and deposited, and afterwards be pressed, without the need of making it water-tight, or without the mass itself having any bottom.

In the case of a wall, or other erection of an embankment, or for other purposes, being to be constructed on ground which, though dry at the time of low water, is considerably, say five or six feet, under water at the time of high water, the foundation in that case may be laid in distinct masses, built upon the spot contiguous to one another or not; of large dimensions, or small, like piles, to such an height as that a flat bottomed vessel, loaded with the requisite weight, may be grounded upon them, whereby the stability of the work may be ensured before the superstructure is proceeded with, with the same ease as if the work had been more under water. In regard to the masses proper for forming the foundations of structures on land, in the case of the ground being such as though at the surface it be unfit for the support of the structure, yet there being a firm stratum at no great depth, but varying at different parts under the scite of the structure, supposing it be required to make the structure rest on the ribs or walls dividing the bottom into squares, piers, on which, by the turning of arches from one to the other, or otherwise, an entire support for the superstructure may be found at the surface of the ground, or above it, for the forming of those piers. Let distinct masses of stone, brick-work, or other such materials, be built up, standing first on the surface of the ground, sinking down more or less during their construction; and when built up to such height from their bottoms as may be supposed sufficient to reach to the solid ground, let weights of any kind, such, for instance, as iron ballast, be laid upon them, to press them through the yielding soil on to or into the hard stratum; the foot of each pier being, if requisite, adapted in shape to penetrate the soil with or without a shoe of cast-iron, or other materials, particularly suited to the purpose; or let this pressure be assisted or be given wholly by percussion, applying some intermediate substance upon the head of the piers, for the beater to strike upon, with such other precautions as to the weight and velocity of the beater as are known to be suitable to the forcing down brittle materials without injury. In cases where the stability of the structure is made to depend on the extent to which the foundation is spread for procuring the requisite support, having estimated the weight, which a given extent, say a yard square, of the foundation, under the different parts of the building, is required to sustain; and having probed the ground, to form some opinion of the depth to which a square yard of surface must be pressed before it will support that weight, let distinct masses be built up perpendicularly on bases of the extent of, say a yard square, contiguous to one another, over the whole scite of the foundation, and up as high as it is supposed they will be pressed into the ground, each mass respectively more or less, in consequence of any variations there may be in the nature of the ground, or in the weights to be supported by different parts of the foundations. Then let the requisite weight be applied upon each mass respectively, or, if the means be easy, on several contiguous ones at the same time; or (as before) let percussion be employed either to a degree calculated to be at least equal to that of the requisite pressure by weight, or let weight and percussion be jointly employed, until the whole of the distinct masses, constituting the foundation, have been submitted to the requisite pressure. In cases where the pressure, which different parts of the foundation will have to support, is very different, as that of the foundation for the steeple of a church compared to that of the lighter parts, let the mass or masses forming the foundation for the heavier parts, be always distinct from those for the lighter parts, and let them be pressed with a proportionably heavier weight. These masses when placed contiguous to one another in a proper direction, one with regard to the other, may then be pressed down, and when pressed

pressed down, they may be connected together before the superstructure is proceeded with; and in some cases it may be expedient to make these masses no larger than piles of wood, to which, however, they might be preferable, as being of cheaper and more durable materials.

EXPLANATION of FIGURES in PLATE 1 of BRIDGES.

"*Figure* 1, (*Plate* 1) A, section. B, plan of a foundation mass of brick-work, for a wharf wall in deep water, *b b b*, parts added gradually to the bottom.

Figure 2, A, section of a mass of brick-work to form part of an embankment, and at the same time to serve other purposes of an ordinary building; part of which shews the superstructure, and the parts gradually added to the bottoms to strengthen them as the superstructure advances, and as by that means a sufficient buoyancy is obtained. B, plan of the same.

Figure 3, A, section. B, plan of a cylindrical mass of masonry or brick-work, applicable for the foundation of a break-water, or for other purposes. The lines *a a* distinguish the superstructure and the parts added.

Figure 4, A, longitudinal section. B, transverse section. C, plan of one of the constituent parts to be prepared ashore for the bottom of a mass of any extent, which may be formed by a number of such constituent parts put together afloat."

Wooden Bridges now demand our attention. There are various methods of constructing wooden bridges, so as to answer valuable purposes, even to last a very considerable time. The simplest case of these edifices is that, in which the road-way is laid over beams placed horizontally, and supported at each end by piers or posts. This method, however, is deficient in strength, and width of opening: it is therefore necessary in all works of magnitude, to apply the principles of trussing, as used in roofs and centers. Wooden bridges of this kind are therefore stiff frames of carpentry, in which, by a proper disposition, beams are put, so as to stand in place of solid bodies, as large as the spaces which the beams enclose; and thus two or more of these are set in a butment with each other, like vast arch stones. One of the most important points to be considered in wooden bridge building, is the seasoning and preparing of the wood, so as to make it lasting. In seasoning of wood for this purpose, the following particulars should be attended to: it is well known that the decay of fir timber is generally owing to the sappy nature of its exterior surface, which is by no means capable of being removed by any immediate application of paint, previous to its being seasoned: on the contrary, it has been proved, that such an application is actually injurious, since it hinders the free admission of air and heat, which would have the property of extracting that sappy quality which so much contributes to decay and rottenness. In consequence of this practice, the sap strikes inwardly, and makes its way to the heart of the wood, the substance of which is presently destroyed. As a means of preventing this evil, some burn and scorch the timber over a flaming fire, turning it about till every side acquire a sort of crusty surface; and in doing this, it necessarily follows, that the external moisture is dissipated. After this process, a mixture of pitch and tar, sprinkled with sand and powdered shells, may be advantageously applied to the parts under water. Those more in sight, after being well scorched, and while the wood is hot, should be rubbed over with linseed oil, mixed with a little tar. This will strike deeply into the grain of the wood, and will soon harden so as to receive as many coats of paint as may appear necessary. It has been found that fir timber, this prepared, is nearly equal to oak for durability.

Palladio has given several excellent designs of wooden bridges, *Figure* 1 *Plate* 2, *of Bridges*, one of which was erected on the river Cismone, which separates Italy from Germany, and is 100 feet wide; this width is divided into six equal parts, and at the end of each part, excepting at the banks, which are strengthened with pilasters of stone, the beams are placed, that form the breadth of the bridge, upon which, a little space being left at their ends, were placed other beams lengthways, which form the sides. Over these, directly upon the first, the king posts are disposed on each side; these king posts are connected to the beams, which form the breadth of the bridge, by means of irons passing through the projecting ends of the beams, and bolted and pinned through both. The invention of this bridge Palladio considers as very worthy of attention, as it may serve on all occasions where posts cannot with convenience be introduced in the river. He describes also other methods of constructing wooden bridges, without posts in the water, like the fore-mentioned. The bridges after the first method are to be made in this manner: *Figure* 2, the banks being strengthened by pilasters when necessity requires, one of the beams forming the breadth of the bridge is to be placed with one end upon the pier, and the other end abbutting against the first queen post, which is to be connected with the beams by irons. Then the second beam being placed at a distance equal to the space between the first beam and the pier, which is to be supported in like manner with a queen, and strut and queen posts, and thus proceeding, as far as required, observing to have a king post in the middle of the length, in which the struts meet both ways, and collar beams between all the posts, which stiffen and support the whole construction. It should be recollected that when bridges are constructed after this manner that they are to be wider at the extremities, and contract towards the middle.

The bridge represented in *Fig.* 3, is also from Palladio. Its upper part, which is the support of the whole, is inscribed in a flat segment of a circle;

the braces which go from one king post to another, are so disposed, that they cross each other in the middle of the spaces between the king posts. The beams that form the floor of the bridge are bound to the king posts, with irons; and for still greater strength struts may be added at each end, reaching from the piers to the first beams.

The design delineated in *Figure* 4, may be made with a greater or less arch than is there shown. The height of the bridge in which are placed the braces between the king posts, Palladio recommends to be an eleventh part of the span. The French army destroyed in the year 1799 at Schafhussen in Switzerland, a wooden bridge, which was erected in the year 1740, by a carpenter of Appenzel, named Ulric Grubenman. At that place the Rhine is exceedingly rapid, and several stone bridges, erected by eminent architects, had been repeatedly swept away by the torrent. In consequence of this, the abovementioned ingenious mechanic, offered to erect a wooden bridge, with only one arch, and which should overcome every difficulty, though the river at that place is near four hundred feet across. The magistrates of Schafhusen would not consent to his proposal, but required that it should be built with two arches, and that the middle pier of the old bridge should be employed for that purpose. Ulric Grubenman obeyed; but framed his timbers on so curious a principle, that he has left it a doubt with subsequent architects, whether the bridge really derived any permanence from the middle pier; or whether it would not have been equally as secure, if it had been formed only of one arch. A man of the lightest weight, in walking over it, could feel the bridge tremble under him; and yet waggons with the heaviest loads passed over it, without appearing to be affected by its elastic motion.

This simple but truly ingenious notion of Grubenman has been greatly improved by an engineer in the erection of a bridge in North America. The span of the arch is about 250 feet, and its rise very small.

Figure 6, *Plate* 2, of Bridges represents three beams of the arch. They are formed of logs of timber 10 or 12 feet long of a suitable curvature without trimming across the grain. Each beam is double, and consisting of two logs applied to each other, side to side, by breaking joints. They are united together by wedges and keys, driven through them at short distances, as at K, L, &c. by the method illustrated in the joining of timbers sideways, *see Article Carpentry*. This being understood, we proceed to exhibit a method by which a number of beams may be united together, so as to compose an arch of any thickness. The beams have other mortises worked out of their inner sides, half out of each half of the beam, and the mortises formed as described in the article alluded to above. Long keys B B, C C, are then made to fit them properly, the notches being so placed as to keep the beams at their proper distances from each other, and a long wedge A A driven in between the keys will bind the whole together.

Timbers by this method are brought into a firm and uniform abutment; it is indeed extremely flexible, having nothing to keep it from bending by an inequality of load, but the transverse strength of the beams at the same time. It is evident that this tendency to flexibility may be counteracted by the introduction of diagonal pieces; by which means this construction may be strengthened to any degree of stiffness, and thereby enable it to bear any inequality of load.

When strengthened and supported in this manner it will be decidedly preferable to any construction which has yet been made known; and it possesses besides the peculiar advantage of having any piece of timber taken out and repaired, without disturbing the rest, or by any means endangering the structure.

Iron Bridges.—Modern invention has produced bridges of cast iron, which are cheaper than those built with stone. Iron bridges are the exclusive invention of British artists; and that metal being abundant and cheap, has of late been employed in many works where great strength was required in proportion to the weight of the material.

"Fusible iron, as a material for bridges, has many advantages over stone or wood. It is superior to the first in tenacity and elasticity; and from thence in strength, in the facility of formation, and in the extent of the masses in which it can be exhibited; all which, make it superior, in lightness and cheapness. To wood it is superior in all the same particulars, and in that of durability besides; in which respect alone, it is inferior to stone.

The greatest durability of stone, arises in the first instance, from its being less acted on by the weather, and in the second, from its experiencing less vibration from the motion of carriages on account of the great masses in which it is used. But there are several ways of guarding against the deficiency of iron in these respects; paint will prevent corrosion from rust for many years, and instances could be shewn, where cast iron carriages of garrison guns, have been preserved thus, in an unimpaired state, from the time of the last king William, and the vibration can be greatly diminished, if not totally prevented, by the use of triangular framing throughout, and by putting sheet lead between the joints of the frames. But it is probable both evils might be prevented more effectually by the mode proposed by the late Mr. Samuel Wyatt, to the House of Commons, of filling the vacancies between the iron frames, with some compact cheap material, and none would be more effectual for this purpose, or perhaps cheaper in the end, than brick cemented by Roman cement, or pozzolana, or tarras, which, owing its binding

binding nature chiefly to iron oxyd, would unite to the iron of the bridge in the closest manner, and defend it from every access of air, while the increased mass that would be thus produced, would annihilate vibration, or reduce it to an imperceptible quantity. But as lightness is a desirable quality in these bridges, perhaps it might be advisable to form hollow bricks purposely for this use; which, on account of the more complete baking, or burning in the kiln, of which they would be capable, would, perhaps, be equally durable as any stone. As a proof of which opinion, the thin bricks used by the Romans, are still in perfect preservation in many places. Filling-up the intervals of the iron bars would also have the advantage of preventing almost entirely their expansion and contraction from change of temperature.

Iron may be used for bridges either on the principle of equilibration, as stone is, or on that of connection by framing, as wood is in some bridges, but more generally in roofs. For large bridges, the first is preferable, according to the best opinions; but probably the latter mode would be found cheaper for small bridges. There has been one specimen of a wooden bridge built on a very different system from others, (of which many models are preserved though the French have destroyed the original) that seems worthy of being imitated in iron, on a greater scale, which is the bridge of such a curious structure that stood so many years at Schafhaussen; and it is probable if the model was studied with this view by an experienced engineer, many useful ideas might be obtained on the subject. The greater flatness of the arch, which iron admits of, is an advantage it has over stone, which should not be omitted. It is capable of demonstration, (and has been proved, see Mr. J. W. Boswell's paper on Roads and Wheel Carriages, inserted in vol. 17, of the Repertory of Arts, &c.) that every increase of ascent in a road, adds to the expence of conveying goods over it, in a greater degree than has been suspected. A lofty arch has in this respect all the disadvantages of a high hill, while a flat arch either affords a level road, or one nearly so."

"The difficulty of preparing centering for the large arches (the capability of producing which is one of the greatest advantages of the art of framing iron bridges) is now in a great measure removed, by the ingenious mode proposed by Mr. Telford, in his Report to the House of Commons on the proposed bridge over the Menai." *See Repertory of Arts, &c. No.* 114. For the method of constructing and centering, after the ingenious mode proposed by Mr. Telford, *see Center, article* CARPENTRY.

The first iron bridge of any importance seems to be that of Colebrookdale, in Shropshire. This bridge is composed of five ribs, and each rib of three concentric arcs connected together by radiating pieces. The interior arc forms a semicircle, but the others extend only to the cills under the roadway. These arcs pass through an upright frame of iron at each end, which serves as a guide; and the small space in the haunches between the frames and the outer arc, is filled in with a ring of about seven feet diameter. Upon the top of the ribs are laid cast iron plates, which sustain the road way. The span of this arch is 100 feet 6 inches, and the height, from the base line to the centre, 40 feet. The road over the bridge is 24 feet wide, and is imbedded with clay and iron flag a foot deep. The most elegant and ingenious structure of this kind, is the bridge erected over the Wear at Sunderland, by R. Burdon, Esq. being the result of an invention guaranteed to him by letters patent, dated September 18, 1795, and which he describes as follows: "I, Rowland Burdon, do declare, that my invention consists in applying iron, or other metallic compositions, to the purpose of constructing arches, upon the same principle as stone is now employed, by a subdivision into blocks, easily portable, answering the key stones of a common arch, which, being brought to bear on each other, gives them all the firmness of the solid stone arch; whilst, by the great vacuities in the blocks, and their respective distances in their lateral position, the arch becomes infinitely lighter than that of stone; and, by the tenacity of the metal, the parts are so intimately connected, that the accurate calculation of the extrados and intrados, so necessary in stone arches of magnitude, is rendered of much less consequence. The connecting principle of these iron blocks will be better understood by a reference to the annexed plate of bridges, where *Figure* 6 represents a block of cast iron, five feet in depth from A to A, and four inches in thickness: having three arms B, B, B, and making a part of a circle or ellipsis; the middle arm is two feet in length from B to C, and the other two are in proportion. On each side of the arms are grooves three-quarters of an inch deep, and three inches broad, for the purpose of receiving maleable or bar iron; and in each arm are two bolt holes. D, *Figure* 7, represents two of these blocks united together, and the joints confined to their respective positions by the bar iron on each side of the arms, as at E, E, E: which, with other similar blocks, so united and bearing upon each other, becomes a rib. F, F, *Figure* 7, are hollow tubes, six feet long, and four inches in diameter, having shoulders at each end, with holes answering to those of the blocks. G is a block of another rib, connected with the former by the tubes F, F, placed horizontally. Through the holes in the shoulders and arms of the block and bar iron are bolts (fastened with cotterels or forelocks) as at H, H, H, H. The blocks being united with each other in ribs, and the ribs connected and supported laterally, by the tubes, as above described, the whole becomes one mass, having the property of key-stones cramped together.

The bridge consists of a single arch, whose span is 236 feet; and as the springing stones on each side project

project two feet, the whole opening is 240 feet. The arch is a segment of a circle whose diameter is about 444 feet, its versed side being 34 feet; the whole height from low water about one hundred feet. A series of one hundred and five blocks form a rib and six of these ribs compose the width of the bridge. The spaces between the arch and the road-way are filled up by cast iron circles, which touch the outer circumference of the arch, and at the same time support the road-way, gradually diminishing from the abutments towards the centre of the bridge. Diagonal iron bars are laid on the tops of the ribs, and extended to the abutments to keep the ribs from twisting. The superstructure is a strong frame of timber planked over to support the carriage road, which is composed of marl, limestone, and gravel, with a cement of tar and chalk immediately upon the planks to preserve them. The whole width of the bridge is thirty-two feet. The abutments are masses of almost solid masonry, twenty-four feet in thickness, forty-two in breadth, at bottom, and thirty-seven at top. The weight of the iron in this bridge amounts to 260 tons; 214 of these are cast, and 46 maleable. The whole expence was 27,000l. A very elegant bridge was lately erected over the river Thames at Staines, by the ingenious Mr. Thomas Wilson, who was employed by Mr. Burdon, in the erection of the preceding bridge. This bridge consisted of a single arch, 181 feet in span, and 16 feet 16 inches in rise, being a segment of a circle whose diameter is 480 feet. The blocks of which the ribs were composed, were similar to those in the Wearmouth bridge, except that these had only two concentric arcs instead of three, as at the latter. The arcs were cast hollow, and the blocks connected by means of dowels and keys. Four ribs formed the breadth of the arch, which were connected together by crossed frames. The spaces between the arch and the road-way were filled up with circles, which supported a covering of iron plates an inch thick; on this was laid the road-way, twenty-seven feet wide. 270 tons was the weight of the iron employed in the bridge, and 330 of the road-way. This elegant bridge, which was considered by far the most complete in design, and the best executed, has fallen, but under circumstances rather to prove its superiority, than to depreciate the design or the execution; for the iron-work did not give way until the stone abutments first yielded; the fault was therefore in the construction of the abutments, and not in the iron framing.

Draw-Bridge, one that is fastened with hinges at one end only, so that the other may be drawn up; in which case, the bridge stands upright, to hinder the passage over a ditch or moat.

Flying-Bridge, one made of leather boats, pontoons, casks, hollow beams, &c. laid on a river, and covered with planks, for the passage of an army.

Flying-Bridge, a bridge composed of one or more boats, connected together by a sort of flooring, and surrounded with a ballustrade or railing; having also one or more masts, to which is fastened a cable, supported at proper distances by boats, and extended to an anchor, to which the other end is made fast, in the middle of the water. This contrivance permits the bridge to move from one side of the river to the other, without any other help than that of the rudder. These bridges consist sometimes of two stories, for the quicker passage of a great number of men, or that infantry and cavalry may pass at the same time.

Floating-Bridge, is generally constructed of two small bridges, laid one over the other, in such a manner as that the utmost stretches and runs out, by the help of certain cords running through pullies placed along the sides of the under bridge, which push it forward till the end of it joins the place it is designed to be fixed on. When these two bridges are stretched out to their full length, so that the two middle ends meet, they are not to be above four or five fathoms long, because, if longer, they will break.

Bridges of Boats are made of wooden or copper boats, fastened with stakes or anchors, and laid over with plank.

Pendent or Hanging Bridges, often called *Philosophical Bridges*, are those which are supported only at the two ends on butments, without posts or pillars. Instances of such bridges are given by Palladio and others. The celebrated Dr. Wallis gives the design of a timber bridge seventy feet long, without any pillars or supports whatever. Dr. Plot also informs us, that there was formerly a large bridge of this kind over the Castle ditch at Tutbury, in Staffordshire, constructed of pieces of timber only a yard long each, and without any sort of prop whatever.

Rushen Bridges are made of large sheaves of rushes, covered with planks: they are used for crossing of ground that is boggy, rotten, or miry.

BAKING.

Baking is the art of preparing bread, or of reducing meals of any kind, whether simple or compound, into bread.

Man, who appears to be designed by nature to eat of all substances that are capable of nourishing him, and still more of the vegetable then the animal kind, has, from the earliest times, used farinaceous grains as his principal food; but as these grains cannot be eaten in their natural state without difficulty, means have been contrived for extracting the farinaceous part, and of preparing it so as to render it a pleasant and wholesome aliment.

Those who are accustomed to enjoy all the advantages of the finest human invention, without reflecting on the labours it has cost to complete them, think all these operations common and trivial: no wonder that to such there should appear nothing more easy, than to grind corn, to make it into a paste, and to bake it in a oven.

It is, however, certain, that for a long time men no otherwise prepared their corn, then by boiling it in water, and forming viscous cakes, which were neither agreeable to the taste nor easy of digestion. To make good bread, it was necessary to construct machines for grinding and separating the pure flour with little labour and trouble; and inquires, or perhaps accident, which some observing person availed himself of, discovered, that flour, when mixed with a certain quantity of water and moderately heated, would ferment, by which its viscidity would be nearly destroyed, and would make bread more pleasant to the taste, and easy of digestion.

There are few nations who do not use bread, or a substitute for it. The Laplanders having no corn, make a kind of bread of dried fish, and the inner rind of the pine, which last is added to make a dry food, for which mankind seem to have an universal inclination, in preference to that of a bland, slippery mucilaginous nature.

This is not commonly accounted for, but it seems to depend on very simple principles. The digestion of our food requires the mixture of the animal fluids in every stage; among others the saliva is necessary, which requires dry food to bring it forth; fluid aliments do not remain long enough in the mouth to produce this effect, which is the reason we use bread with our meals.

When, therefore, it is considered how large a portion of our sustenance is derived from bread, and that it forms part of every meal; it is surprizing that the art of bread-making has not been, till of late years, a subject of scientific investigation. The researches of Count Rumford and M. Parmentier have, however, at last induced a great number of ingenious men to apply themselves to the study of this most important subject, who by the results of their experiments, have rendered the art of making and baking good bread more certain and economical.*

To bake well requires many precautions, and a degree of skill, which practice alone can secure. It is probably owing to these circumstances, connected with the real importance of the art, that those who first began to pursue it as a profession, were held in such high estimation in their several nations. At Rome, into which regular bakers seem to have been introduced from Greece about the year of the city 583, they were so much esteemed, as to be occasionally admitted into the senate;, and to enable them the better to devote more of their time to the study of their business, they were altogether exempted from guardianships and other troublesome offices, to which the rest of the Roman citizens were liable.

In treating of this subject we shall pursue the following arrangement, in conformity to the plan adopted by Mr. Edlin, in his treatise on bread-making.

1. *Observations on the mealing trade.*—2. *Analysis of wheat flour.*—3. *Remarks on yeast.*—4. *On the theory of fermentation of bread.*—5. *On the preparation of bread.*—6. *Substitutes for wheaten bread.*—7. *Remarks on the structure of a bake-house, with observations on the different construction of ovens, &c.*

On the Meal Trade.—The great corn-market in this kingdom, is the Corn-Exchange, in Mark-lane, where on Mondays and Fridays are exposed samples, sent by the farmers and corn-merchants tied up in small bags, with a label on each, stating the number of quarters, and at what plac they are deposited.

Till within the last sixty years, the dealers in corn carried on their trade at Bear Quay, but finding it on many accounts extremely inconvenient, the present Corn-Exchange was erected by a company of proprietors, for their accommodation, and is managed by a committee of three trustrees, chosen by the proprietors, who have allotted seventy-two stands, on which the samples are exposed for sale; sixty-four of which number are leased out to factors; the other eight are reserved for the Kentish Hoymen. The practice of sending samples instead of the article in bulk, we are persuaded is injurious to the purchaser; this evil is expressed by the committee of the House of Commons respecting

* We believe the first regular treatise on the art of bread-making, was written by Mr. Edlin; to which publication we are indebted for much of the information contained in the present article.

respecting corn, who state, in their report, that this practice enables the broker to keep back, or expose the quantity on sale as best suits his ends.

To this market the millers, mealmen, and corn-chandlers from different parts of the country, resort to transact business. The broker has a commission of one shilling per quarter for selling foreign wheat, and sixpence per quarter, for all that comes coastwise; The buyer has to pay the corn-meter one penny per quarter, as a consideration for ascertaining that the quantity in bulk correspond to the quantity marked on the sample bag. The purchaser is not compelled to complete his bargain, unless the report of the corn-meter makes the quantities agree. This saves the buyer much trouble, as it frequently happens that the corn does not arrive at Bear Quay for many days after the purchase is made. Most country towns have their markets on stated days, where the corn is commonly exposed in bulk by the farmer, which is a much fairer way; as by this the purchaser is enabled to judge how far the market is ill or well supplied with grain. The custom of preventing the sale of corn till a particular hour, is also a very proper one, and although we disapprove of the interference of Government in matters of trade, we cannot see any evil that could possibly accrue from compelling all sales of corn to be made in the market, which if inconvenient to be sent in bulk, might certainly be done by samples

MANAGEMENT OF THE GRAIN IN GRANARIES.—After the grain is purchased it is sent to the granaries, which, are large buildings of many stories, each of which consists of one entire apartment, where, by turning and screening, it is deprived of its superfluous moisture, and rendered more fit for grinding into flour. These operations are performed in the following manner; the corn being deposited on one of the floors, it is tossed by means of shovels from one end of it to the other, in which operation the dust and any other light substance falls to the floor, whilst the grain being heavier, reaches the farther end of the loft.

It is then screened and spread on the floor about half a foot thick, turning it twice a week, and screening it once, which management must be continued for the first two months. The grain is then laid a foot thick, and for the two next months is turned once a week, and screened less frequently. This management is to be continued for five or six months, when it may be encreased to two feet thick, and the former operations repeated as occasion requires, which will be more frequent in damp than in dry weather.

After a year it may be increased in thickness to three feet and turned and screened once in three weeks or a month. By this means corn has been kept in this country more than thirty years, and it is observed that the longer it is kept the more flour it yields, and the purer and whiter is the bread which it makes.

Corn is preserved on the Continent in the following manner, for fifty or one hundred years. Grain treated in the same manner as before described, to dry out all superfluous moisture, is deposited in a pit and covered with quick lime a little wetted; this induces the corn to shoot to about the depth of an inch, forming thereby a crust which is impervious to air and insects. The pit is then secured by planks laid over it and fastened together.

In Lord Gardenstones' travels, we meet with the following account of preserving corn at Geneva. While the grain continues new it is turned about once every twenty days. till it requires a sufficient degree of firmness, which generally requires two years. It is then moderately kiln dried, and stowed in the lowest flat of the granary, as high as the floor of the next flat; on this manner they proceed lessening the quantity as they rise in each flat, for the purpose of saving expence. By this method they preserve the grain sound for many years.

Mr. Edlin relates that, after a thunder storm, corn that is perfectly dry and sound before, will frequently feel quite clammy, and that, if not very well turned and dried, it will be totally spoiled. This effect does not happen to corn above a year old, unless it be such as was not sweated sufficiently in the straw, before it was thrashed out.

To preserve grain from insects, Mr. E. recommends frequent screening, ventilation, and lodging it dry. As a further preventative, he recommends the floors being rubbed with garlic and dwarf elder, the smell of which will drive them away.

Good wheat should look plump, feel heavy in the hand, and be of a clear transparent amber colour; and when masticated some time in the mouth, a considerable portion of a thick glutinous matter, free from meal, will be left behind. Its taste should be sweetish. Wheat with a thick skin yields less meal and darker, and of course fetches a less price. That part of the grain which produces the finest flour is the heart or centre; this meal ferments readily; but the meal produced from that part of the grain immediately under the coating, and which being softer than the heart, is not so easily reduced to powder, is of an inferior kind, and ferments with yeast with difficulty.

Having shewn the manner of preserving grain, we shall now endeavour to give some account of the manner of its being ground and manufactured into flour. Mills for grinding corn are generally called grist-mills, and are mostly driven by water. The building of the largest mills is commonly three stories high; on the first floor the corn is ground by means of two mill stones one above the other; the lower stone is fixed, but the upper one turns upon a spindle, to which motion is given from the water wheel by means of toothed wheels acting in each other. The surfaces f the two stones, between which the corn is ground, is not flat or plane, the upper one being hollow, and the lower one rounding upwards, or convex; but as the

the concavity or hollow of the upper stone exceeds that of the convexity or rounding up of the lower, it must be obvious, that the stones come nearer together at the edges than in the middle. The corn being drivelled from the happer through a hole in the centre of the upper stone, is worked between the stones near two-thirds of the way from the centre to the edges, where it begins to be ground, the space at that place being but one-half or three-fourths of the thickness of the grains of corn; it may, however, be increased or diminished whenever the miller thinks proper, by raising or sinking the upper stone, which will of course make the flower finer or coarser. There are furrows cut in the stones, from the centre to the sides, which causes them to cut quicker. When the corn is quite reduced to flour, it is thrown out of the mill by the centrifugal force of the upper stone, through a hole made for that purpose into a trough, and from thence descends by means of a wooden trunk into a bin on the ground floor, which is divided into two parts by a partition, and provided with a cover. The bunt or sieve through which the meal passes to rid it of its bran, is a skeleton of a cilindrical form, made of iron bars, and extending from one end to the other of the bin, not horizontal but a little inclining at one end. This skeleton is covered with an exceeding fine wove wire for the first half its length, and the other half with wove wire somewhat coarser; into the upper end of this bunt the meal is conducted, and a rotary motion given to it by connecting it with the machinery; the fine flour falls into the first division of the bin, and the coarser into the second, the bran is discharged at the lower end into the joggling screen, to separate what meal is remaining in the bin, which runs downs in a locker below. The meal thus separated is again caught by a second screen, which in the same way separates the twenty-penny, and what passes down the third screen is called rough stuff, and is made into what the corn chandlers call pollard. What comes through the first division of the boult is termed fine or household flour; that which passes through the second division is called sharps; these are suffered to remain till a sufficient quantity is collected when they are re-ground, the stones being sat closer together for that purpose and boulted through the cloth, No 17, this is found to produce better flour than if the stones were set sufficiently close the first grinding, and what does not pass through this cloth is passed through a cloth of a coarser kind, No. 15, which forms the fine middlings, and that which will not pass No. 15, is dressed through a still coarser, No. 11, and is denominated coarse middlings, the refuse of which is mixed with the pollard. Sharps are not always re-ground, as they are found to make a biscuit of an excellent quality, which keeps longer then when made of flour alone; it is sold to contractors for the supply of the navy.

The finest English wheat that can be procured is ground, without the admixture of foreign, and sold to the pastry cooks and others, as Hertfordshire whites.

This is the usual course of the mealing trade, and the following is the produce of a quarter of wheat.

Fine Flour......	5 Bushels 3 pecks.
Seconds........	half a bushel.
Fine Middlings..	1 Peck.
Coarse ditto....	half a peck.
Bran..........	3 Bushels or half a sack.
Twenty-penny..	Ditto.
Pollard........	2 Bushels.

The flour is now put into sacks, each sack containing five bushels or two hundred and eighty pounds. Flour is better for keeping a short time after being ground, as it seldom makes light bread when new.

Fine flour is very apt to breed insects if kept too long after being ground, which are very destructive; flour so infested must immediately be made into bread.

The following account, taken from the second volume of "the Repertory of Arts and Manufactures," may serve as a caution to those who may have large quantities of meal in store at one time. On the 14th of December, 1795, about six o'clock in the evening, there took place in the house of M. Giacomelli, baker, in this city of Turin, an explosion that burst out the windows and window frames of his front shop, and the report was so loud as to be heard at a considerable distance. At the moment of the explosion a very bright flame, which lasted only a few seconds, was seen in the shop which contained near three hundred sacks of flour. In this place a boy was employed in emptying out some flour by the light of a lamp. He had his face and arms terribly scorched by the explosion, his hair was burnt, and it was more than a fortnight before his burns were healed."

It does not appear that the flour, which caused the above accident, was damp; and Count Morozzo, who gives the account, mentions several explosions which happened at different places and times. We insert this account to guard those who may have large quantities of flour under their care, to prevent their carrying candles into the store, as it may be attended with the most dreadful consequences.

We shall now notice some experiments which were made by Mr. Edlin to ascertain the constituent parts of weight.

This gentleman took one pound of the seed of wheat that grew on a well-cultivated soil, and ground it in a hand mill; the meal was then sifted through a fine lawn sieve, and when the flour was separated there remained three ounces of bran and twelve ounces of fine flour: this last was put into a hair sieve, and a stream of water gradually poured over it, whilst he kneaded it into a paste; more water was added from time to time till the following appearances

appearances took place: A glutinous substance remained in the hand, which was very elastic. The powder which subsided to the bottom of the vessel was starch, and the liquor in which the foregoing articles were suspended, was of a brown colour and a sweetish taste. These were all put by for future experiments, the result of which was as follows: viz.—That the glutinous elastic substance, when dried, became perfectly brittle, resembling glue, and weighed six drachms. Mr. Edlin is of opinion that to this gluten wheat owes the property of forming an adhesive paste, and its fecility to rise with leaven, not that it contributes immediately to produce fermentation, which is by no means the case; but in forming a more tenacious dough or paste. This property exists only in a small degree in barley, and is altogether wanting in potatoes, which our author thinks is the cause why bread, made from these two articles, is so difficult of fermentation. That this is the case, seems certain from the experiments of M. Beccari, of Bologna, and Dr. Cullen, who, by adding this substance to barley and potatoes, produced better bread from each, then could be obtained without this addition. Parmentier asserts that bread may be made from potatoes alone, this opinion, however, seems to be contrary to the experiments of Mr. Edlin and Dr. Pearson, both being decidedly of opinion that this root cannot be fermented so as to make bread without the admixture of wheaten flour. Hence, they conclude, that no farinacious or mealy substance can be made into good bread, that has not the three constituent parts of wheat; for, if to the starch of potatoes, some of this glutinous substance be added, with yeast and water, it will not form a bread, owing to the absence of the saccharine or sugery extract, on which the process of fermentation depends, and which, if this last substance be added, even in a concentrated state, will immediately commence.

It has not yet been ascertained in what proportion the glutinous substance is found in wheat, Mr. Winter states that it is less in wet than in dry seasons, and Mr. Edlin thinks it more abundant in wheat growing on land well manured, then from that which is the produce of neglected soils.

The fæcula, or starch, deposited in the bottom of the vessel, was next dried, and was found to be fine white starch; as this forms by much the most considerable part of the grain. Mr. Edlin, thinks it the principal elementary substance of bread, and this opinion is strengthened by the fact of many thousands of the inhabitants of Ireland, living principally upon potatoes, which contain starch, in considerable quantity, and are altogether destitute of gluten, which has been so much insisted upon, as being so extremely nutritive; this is also corroborated by experiments on feeding animals. It seems also certain, that the fœcula or starch of wheat will not make bread without the addition of the glutes and saccharine extracts. The next experiments were made on the sugary, or saccharine extract, which proved that however small the quantity may be which wheat contains, yet its presence is absolutely necessary in the formation of good bread.

Mr. Edlin next made a variety of experiments on the composition of yeast, in order to ascertain what share it has in producing fermentation in bread. He found that the same effect was produced by using the fixed air, or sulphuric acid gas, which was disengaged by pouring some diluted sulphuric acid upon powdered marble; he also collected the gas produced by the fermentation of some newly tunned beer, which likewise produced good bread, similar in all respects, to that made in the usual way. From these experiments he concludes that the principles which enter into bread, are gluten, starch, sugar, and fixed air.

THEORY OF FERMENTATION IN BREAD.

In order to make this understood by persons altogether unacquainted with chemistry, it is necessary that the following facts should be known:—that there are three states of fermentation, which takes place in the following order, viz. the Vinous, which produces wine, beer, &c. the Acetous, and Putrid. All fermentation is an intestine motion of the constituent particles of a moist, fluid, mixed, or compound body, by the continuance of which motion the particles are gradually removed from their former situation or combination, and again, after some visible separation is made, joined together in a different order and arrangement, so that a new compound is formed.

The usual method of making bread with yeast, is very simple, and soon performed. The yeast is added to a part of the flour and well kneaded; this in a short time swells and rises in the trough, and is called by the bakers setting the sponge. Afterwards the remainder of the flour is added, with a sufficient quantity of water to make it into dough, the whole is then left to ferment and rise.

The water being added to the yeast, warm, extricates the air in an elastic state, and the whole being well diffused and mixed with the mass, every particle must be raised; the air being kept from escaping by the viscidity of the dough. In this state it is neaded, and made up into loaves, which are then baked, the increase of heat disengaging more of the fixed air, which is further prevented from escaping by the forming of the crust, the process continuing, the superfluous water is driven out, and the bread becoming firmer, retains that spungy hollowness which distinguishes good bread.

From what has already been said, it appears that the saccharine extract of the wheat flour, in consequence of moisture, has its constituent principle disengaged, the oxygen seizing the carbenaceous matter, and forming carbonic acid, which is disengaged in the form of gas, occasioning the intestine motion

motion and swelling of the dough just described; but this process, if left to itself without the addition of yeast, is extremely slow. This is what is called leavened bread.

In making bread without yeast, the process is more tedious, a small quantity of flour is wetted, and allowed to remain several hours covered up. In this case the water is decomposed; the oxygen of that fluid uniting with the sarcharine extract, bring on fermentation, which is not of a vinous but of an acetous nature, more flour and water are from time to time added to the leaven, till a sufficient quantity is ready for baking. Much nicety is required in conducting this operation, which, if left too long will make the bread sour, and if time enough is not allowed for its raising, heavy bread will be the result.

There are many articles in use for exciting speedy fermentation in flour, which may be all brought under the two following heads: either they are impregnated with carbonic acid gas, or contain the principle of acidity; hence we are able to account why light bread is made at Paris with the waters of Genesse, without yeast. At Pyrmont the same thing is done with Saltzer water, and in England with artificial Saltzer. There are also two springs at Saratoga, in America, which are possessed of the same properties. All these waters are highly impregnated with fixed air.

In warm climates where no beer is brewed, the inhabitants commonly raise their bread by the acetous method as described before, which is generally to be perceived by the sourness of their bread. It is, however, possible to make good bread by this process, and the mode is often adopted on board our men of war, in the West Indies, by mixing water which has become sour in casks, with the flour, which will excite fermentation almost as speedily as yeast.

In the East Indies, where fermentation is extremely quick, a liquor, called toddy, procured by an incison being made in the branches or fibres of the cocoa nut tree, is used to promote fermentation.

OF THE PREPARATION OF BREAD.

In order to prepare bread, flour and water are kneaded together into a tough paste; this contains the principles of flour, but very little altered, and not easily digested by the stomach. The action of heat produces a considerable change, it renders the compound more easy to masticate as well as to digest. Bread made in this manner is called unleavened, and is used for shipping in considerable quantities; but most of the bread used in France, Germany, and other European countries, is made to undergo, previous to baking, a kind of ferment. The effect of this fermentation is found to be, that the mass is rendered more digestable and light, by which expression it is to be understood that it is more porous, by the disengagement of an elastic fluid that separates its parts from each other, as before explained, and greatly increases its bulk.

The operation of baking puts a stop to this process, by evaporating great part of the moisture, and, probably also, by still farther changing the nature of the component parts. Bread made according to the preceding method, will not possess that uniformity which is requisite, because some parts may be mouldy, while others are not sufficiently changed from dough. The same means have been used in this case as have been found effectual in promoting the fermentation of large masses; this consists in the use of a leaven or ferment, which is a small portion of some matter of the same kind, but in a more advanced state of fermentation. After this leaven has been well incorporated, by kneading it into fresh dough, it not only brings on the fermentation with greater speed, but causes it to take place in the whole mass at the same time; and as soon as this dough has, by this means, acquired a due increase of bulk from the air which endeavours to escape, it is judged to be sufficiently fermented, and ready for the oven.

The bread principally used in this country is fermented with yeast, or the froth which arises on the surface of beer, in the first stage of fermentation. When it is mixed with the dough, it produces a much more speedy fermentation than that obtained from leaven, and the bread is accordingly much lighter, and, unless it is improperly prepared, is never sour.

Having thus briefly touched upon the different kinds of bread, we now pass on to its preparation, which we shall divide into three kinds; 1st, unleavened bread, 2d, leavened bread, and 3d, carbonic bread.

1st.—Unleavened bread is that which the Jews eat during their passover; the custom was introduced in remembrance of their hasty departure from Egypt, when they had not leisure to bake leavened, but took the dough before it was fermented, and baked unleavened cakes. In Roman Catholic countries it is still used, and is prepared with the finest wheaten flour, moistened with water, and pressed between two plates, graven like wafer moulds, being first rubbed with wax to prevent the plate from sticking, and when dry it is used.

The common method of making unleavened bread is as follows:—Put a peck of flour into a kneading-trough, three ounces of salt, and a sufficient quantity of warm water; knead them well together till intimately blended, then roll the dough out into thin cakes, and bake them in a quick oven, in order to render them more porous, taking care to turn them during baking.

To make Arabian bread, from M. Neibuhr's Travels.—The modes of making bread are different in different parts of Arabia; but the following manner of pounding the grain, however troublesome,

is in most general practice, and considered pleasanter to the taste than meal, that has been ground in a mill. In the first place, two stones are procured, one convex, and the other concave; the grain is then placed on the lower one, and a man bruises it till it is reduced to a meal; it is then mixed up with water, and divided into small cakes. In the mean time, an earthern pot, glazed on the inside, is filled with charcoal and set on the fire, and when it is sufficiently heated, the cakes are laid on the outside of it, without removing the coals, and in a few minutes the bread is taken off, half roasted and eaten hot.

The wandering Arabs of the desert, when they have not this convenience, use a heated plate of iron, or a gridiron, to bake their cakes; and when these are wanting, they roll the dough into balls, and put it into a fire of camels' dung, where it remains covered up till it is sufficiently penetrated by the heat. Bad as this bread is, it is better than the durra bread, which is in general use among the common people; it is made of coarse millet, kneaded up with camels milk, oil, butter, or grease, pounded together, and then baked in the embers. M. Neibuhr, observes, that he could not eat this bread at first, but the people of the country being accustomed to its use, prefer it to barley bread, which they think too light.

2d. Of leavened bread.—This operation consists in keeping some paste or dough till the acetous fermentation takes place, when it swells, rarifies, and acquires a sourish and rather disagreeable taste. This fermented dough is then well worked up with some fresh dough, which is, by that mixture and moderate heat, disposed to a similar but less advanced fermentation than that above mentioned.

By this fermentation the dough is attenuated and divided, air is introduced, which being incapable of disengaging itself from the tenacious and, solid paste, forms it into small cavities, raises and swells it; hence the small quantity of fermented paste which disposes the rest to ferment, is called the little leaven.

When the dough is thus raised, it is in a proper state to be put into the oven; where, while it is baking, it dilates itself still farther by the rarefection of the air, and forms a bread full of eyes or cavities, consequently light, entirely different from the heavy, compact, visous, and indigestible masses made by baking in fermented dough.

It often happens that bread made with leavened dough, acquires a sourish, and disagreeable taste, which is said to proceed from too great a quantity of leaven, or from leaven in which the fermentation has advanced too far. This circumstance was explained in the last chapter, where it was stated, that unless the principal of acidity is generated, it will not ferment at all. However, as it is a subject that deserves particular investigation, we propose, in the following experiments, to enquire if this disagreeable flavour, when it does occur, can be counteracted.

Mr. Edlin took one pound of wheat flour, and put it into a kneading trough, and mixed it up into a paste with eight ounces of water, at the temperature of 65° of Farenheit's Thermometer. This mixture was placed in 76 degrees of heat. In twelve hours no apparent change had taken place: but, on examining it at the end of twenty-four hours, he observed several bubbles of air, which increased in number on kneading the dough, and on introducing the thermometer, it stood at 70, 1-fourth, an increase of 5, 10-fourths in the heat, in consequence of the fermentation.

At the expiration of thirty six hours he found this little leaven in a complete state of fermentation, and much thinner than on the preceding day; it was also of a sourish taste. He then added three pounds more flour, one ounce of salt, and a pound and a half of water, by weight; the whole was kneaded for about half an hour, and left to ferment again for six hours longer.

It was then made up into a proper consistence for baking, which required eight ounces more flour; and in weighing the whole, it turned out exactly six-pounds, the quantity used in the experiment. His reasons for determining its weight was, to ascertain whether, during fermentation, any sensible quantity of air was absorbed.

It was now divided into six equal portions, and made into as many loaves, These were placed in the oven, and after remaining in that situation half an hour, they were found to be sufficiently baked. This is known by tapping with your finger on the bottom crust, and when done, the sound emitted is sonorous, but if not baked enough, dense. It is a sound difficult to be understood, and can only be learnt by practice.

The loaves were removed from the oven, taken off the tins, and placed on a board; one of them was wrapped in flannel, while the others were exposed to the air. When cold they where all weighed, and turned out five pounds two ounces, fourteen ounces less than when they were put into the oven, and ten ounces more than the flour used in the experiment.

On weighing the loaf that was covered with the flannel, and one of the others that had been exposed to the air, though they were of equal weight when taken out of the oven, yet now the one that was covered up proved to be four scruples heavier than the other, making a difference of three quarters of an ounce in the quartern loaf.

They were both cut asunder, and the bread looked porous, was tolerably light, and absorbed moisture readily; but the taste was sourish; it seemed as if a small quantity of vinegar was added to the dough, but still it was palatable.

On tasting the crusts, that which had been cover- ed

ed up was crisp and easily masticated, while the other was tough, dense, and in every respect disagreeable.

In order to make leavened bread without this sour taste, the following experiment was made.

He took one pound of flour, and mixed it up with eight ounces of water, at the temperature of 68°. This was covered up, and set in a warm place for thirty-six hours, at the expiration of which time, he found it in a state of fermentation, and quite sour.—A quart of warm water was added, and suffered to stand for twelve hours more; the clear liquor was then decanted off, which had a taste similar to diluted vinegar, and a smell not unlike that emitted from an old pickle jar.

Twenty grains of prepared kali was then added to this liquor, which occasioned an effervescence similar to that observed in preparing saline draughts. When subsided, as it still continued sour, the like quantity was again added, which entirely destroyed the acidity; but to be convinced, by a chemical test, a paper was introduced dipped in tincture of turnsol, which it no longer turned red.

It was now evaporated to the consistance of honey, and put by for the night; in the morning crystals of acetated kali were observed.

From the result of these experiments, it may, with probability, be concluded, that, in making leavened bread, one ounce of vinegar is generated from a pound of flour during the fermentation of the little leaven; but as this acid is not necessary, and indeed ought not to be present in good bread, it will be worth while to enquire by what means it might be destroyed, without impeding fermentation.

To one pound of flour was added a sufficient quantity of warm water; this was suffered to ferment as the last (having ascertained the quantity of vinegar generated in a pound of flour) forty grains of prepared kali were mixed with a little warm water and added to the leaven; on kneading it together an instant increase of bulk was observable, during which time, the carbonic acid gass, or the principles of yeast was extricated; to prevent its escape, the dough was sprinkled with a little flour, and covered up with a cloth.

Two hours after it was found to be amazingly increased in bulk, and much more porous than common leaven. Another pound of flour, and a quarter of an ounce of salt were added, and after standing two hours to prove, it was divided into two loaves, and put in the oven.

On comparing it when baked with a loaf of leavened bread with the same quantity of flour in it, it appeared considerably larger; and on cutting it the bread was much lighter and more spungy than common leavened bread, without the least acidity.

TO MAKE LEAVENED BREAD, BY THE HON. CAPTAIN COCHRANE.

Take a piece of dough, of about a pound weight, and keep it for use, it will keep several days very well. Mix the dough with some warm water, not very hot, and knead it with some flour to ferment and spunge; then take half a bushel of flour, and divide it into four parts; mix a quantity of the flour with the leaven, and a sufficient quantity of water to make it into dough, and knead it well. Let this remain in a corner of your trough, covered with flannel, until it ferments and raises properly; then dilute it with more water, and add another quart of the flour, and let it remain and rise. Do the same with the other two quarters of the flour, one quarter after another, taking particular care never to mix more flour till the last has risen properly. When finished add six ounces of salt, then knead it again, and divide it into eight loaves, making them broad, and not so thick and high as is usually done, by which means they will be better soaked. Let them remain on the board to rise, in order to overcome the pressure of the hand in forming them; then put them in the oven, and reserve a piece of dough for the next baking. The dough thus kept, may with proper care be prevented from spoiling, by mixing from time to time small quantities of fresh flour with it.

3d. Of Carbonic bread.—The invention of beer, furnishes a new matter useful in making bread; this is the froth or yeast formed on the surface of these liquors during fermentation. When it is mixed with the dough, it rises better and more quickly than ordinary leaven, and by means of this the finest and lightest bread is made.

Bread well raised with yeast, and baked, differs from the preceding kinds, not only in being less compact, lighter, and of a more agreeable taste, but also in being more miscible in water, with which it does not form a vicous mass, which is of the greatest importance in the progress of digestion, as already observed.

There are several preparations of this kind of bread, made not only with wheat flour, but also with barley, rye, oats, buck-wheat, maize, rice, beans, and potatoes, the principal preparations of which will be detailed in their proper orders.

The common family way of making bread.—To half a bushel of flour add six ounces of salt, a pint of yeast, and six quarts of water, that has boiled; in warm weather, put the water in nearly cold, but in winter, let it be as warm as the hand can be endured in it without causing pain. This is deemed a good proportion, and the mode of proceeding is as follows:—

Put the flour into a kneading trough, or other vessel used for that purpose, and make a hole in the middle of the flour, put the water into it; to which, add the yeast and salt, stir them together, and mix up the flour with it till the dough becomes of a very thick consistence. Cover the whole up warm to ferment and rise, particularly in cold weather; this is called *setting the sponge* and on a due management

nagement of this part of the business, depends the goodness of the bread.

After letting it lie in this state an hour and a half, more or less according to the state of the weather, knead it well together, be not sparing of labour, and afterwards lay the whole thick at one end of the kneading trough, and let it lie some time longer covered up. During this part of the process, the oven must be heated; when that is effected, and properly cleansed from ashes, cinders, &c. make the bread into eight loaves, and place them in the oven as expeditiously as possible, observing to leave a little fire on one side of the mouth of the oven, to give light while setting, and also to prevent the external air from cooling it. Stop the oven up close, and draw the bread out when baked. The proof of its being well fermented and baked, will appear on putting a slice in water; if it is good bread, it will dissolve entirely into a paste, in the course of a few hours, without rendering the water turbid or mucilaginous.

To make French bread.—Put a pint of milk into three quarts of water; in winter let it be scalding hot, but in summer only milk warm. Then take a quarter of a pound of salt, and a pint and a half of good ale yeast; stir it into the milk and water, and then with your hand break in a little more than a quarter of a pound of butter; work it well till it be dissolved, then beat up two eggs in a bason, and stir them in. Take about a peck and a half of the finest wheaten flour, called Hertfordshire whites, and mix it with your liquors. In winter your dough must be pretty stiff, but more slack in summer, so that you may use a little more or less flour according to the stiffness of your dough, but mind to mix it well, and the less you work it the better. You must stir the liquor into the flour as you do for pie-crust, and after your dough is made, cover it with a cloth, and let it lie to rise while the oven is heating. Make it up into bricks or loaves, and put them into the oven: when they have lain about a quarter of an hour turn them to the other side, and let them lie a quarter of an hour longer. When done, do not cover them up as bread usually is, but leave them on the board till they are cold, then chip them all round with a knife, which will be better than rasping, and make them look more spongy, and of a fine yellow colour; whereas the rasping takes off that fine yellow colour, and makes the bread look too smooth.

TO MAKE BROWN WHEATEN BREAD, BY SIR JOHN CALL.

Suppose a Winchester bushel of good wheat weighs fifty-nine pounds, let it be sent to the mill and ground entirely down, including the bran, the meal will then weigh fifty-eight pounds, for not more than a pound will be lost in grinding; it must then be mixed up with water, yeast, and salt, and the dough weighed before it is put into the oven, which will appear to be eighty-eight pounds. Let it be divided into eighteen loaves, put into the oven, and thoroughly baked; after they are drawn out and left two hours to cool, they will weigh seventy-four pounds and a half.

The bread thus made will be found excellent, and fit for any household use; and was the broad bran taken out, of which there may be about five pounds in a bushel of wheat, thus manufactured, it would produce sixteen loaves and a quarter.

TO MAKE BREAD WITH ALL THE BRAN ADDED TO IT, BY T. BERNARD, ESQ.

Take seven pounds of bran and pollard, and fourteen quarts of water; boil the whole very gently over a slow fire. When the mixture begins to swell and thicken, let it be frequently stirred, to prevent its burning to the bottom or sides of the pan. With two hours boiling it will acquire the consistence of a custard pudding; then put it into a clean cloth, and twist it until the liquor is squeezed out: with a quart of which mix three pints of yeast, and set the sponge for twenty-eight pounds of flour. The bran and pollard, which, when the liquor has been squeezed out, is above four times its original weight, before it was boiled, is then to be set near the fire, in order that it may be kept warm. In about two hours the sponge will be sufficiently risen, upon which the bran and pollard, (then lukewarm, but not hot, and into which is to be sprinkled about half a pound of salt), should be mixed with flour, and the whole kneaded up very well together, with a quart of the bran liquor, and it should then be baked for two hours and a quarter in a common oven.

The produce weighed, when cold, will be half as much again as the same quantity of flour would produce in the common way, without the addition of bran. Most of the objections to the use of bran in bread, appear to be founded on a presumption, that no mode of preparation will make any difference in the degree of nutriment to be derived from it as a food. Though the subject is as yet but little understood, yet we have gone far enough to ascertain the fact, that in most kinds of grain some increase of the ordinary nutritive power may be produced by culinary process; the very making of bread affords an example of this increase. In rice it is very great, and in barley meal, particularly when used in soup, its increased power of nutriment may be extended to a surprising degree; as it is now well known, that rice, when increased by water to a solid substance of five times its original weight, or by the addition of milk, to eight times what it originally weighed, is converted from a hard indigestible grain, into a wholesome nourishing food.

To make pan bread.—Put a peck of fine flour into a wooden bowl that has been previously warmed; let it stand before the fire for about an hour, then

then mix up a sufficient quantity of salt and yeast with warm water, and make up the bread at once. Cover it with a cloth and let it stand before the fire for about three hours; then make it up into loaves, and put it into earthenware pans, and set them in a quick oven. When well soaked, and nearly done, the bread must be taken out of the pans, and set on tins for a few minutes that the crust may brown, they must then be taken out, and wrapped in flannel, and when cold rasped.

Bread made in this manner, is much lighter than the common baker's bread, and when cut, puts on the appearance of honey-comb. It is necessary to remark, that the dough must not be so stiff as usual.

TO MAKE BREAD THAT WILL NEVER BE BITTER, BY MR. JAMES STONE.

It frequently happens, in the summer season, that the brewers, in order to prevent their beer from turning sour, are obliged to use more hops than usual: the consequence is, that the yeast is very bitter, and gives a disagreeable flavour to the bread. To obviate this inconvenience, Mr. Stone has recommended the following method of raising a bushel of flour with only a tea-spoonful of yeast.

If you want to bake a bushel of flour, put it into your kneading trough, then take about three quarters of a pint of warm water, and one tea-spoon full of yeast. Stir it, till it is thoroughly mixed with the water; then make a hole in the middle of the flour, large enough to contain two gallons of water. Pour in your small quantity; then take a stick, and stir in some of the flour, until it is as thick as you would make for a batter pudding; then strew some of the dry flour over it, and let it stand for an hour. Then take a quart more of warm water and pour in, and with your stick stir in some more flour, until it is as thick as at first; then shake some more dry flour over it, and leave it for two hours longer, when you will find it rise and break through the dry flour again: you may then add three quarts or a gallon of water, and stir in as before directed, taking care to cover it with dry flour again, and in about three or four hours more, you may mix up your dough, and cover it up warm. In four or five hours more, you may make it up into loaves, and put it into the oven, and your bread will be as light as if you had used a pint of yeast.

It does not require above a quarter of an hour longer than the usual method of baking, for there is no time lost but that of adding the water several times, and the bread is always good and never bitter.

TO MAKE WHEATEN BREAD, AS PRACTISED BY THE BAKERS.

Mr. Edlin wishing to obtain every information on this subject, procured access to a bakehouse, and has given us the following account.

"At three o'clock they prepared to set the sponge, for which purpose, two sacks of household flour were carefully sifted through a brass wire sieve. The following mixture was then prepared. Two ounces of rockey which is a solution of alum * was first put into a tin vessel with a little water, and dissolved over the fire, which bakers call liquor; this was poured into the seasoning tub, and nine pounds of salt was thrown in, over which they poured two pails full of hot liquor; when cooled to 84° of Farenheit's thermometer, six pints of yeast were added; this composition was then stirred well together, strained through the seasoning sieve, and emptied into a hole made in the flour, when it was mixed up with it to the consistency of thick batter. Some flour was sprinkled over the top, when it was covered up, to keep in the heat. This operation is called setting quarter sponge.

In three hours, two pails full more of warm liquor were stirred in, and the mass covered up as before. This is termed setting half sponge.

Five hours afterwards five more pails of warm liquor were added, and when the whole was intimately blended, it was kneaded for upwards of an hour. The dough was then cut into pieces, and thrown over the sluice board, and penned to one side of the trough; some dry flour being sprinkled over, it was left to prove, till about three o'clock in the morning, when it was again kneaded for the space of half an hour. The dough was taken out of the trough, put on the lid, and cut into pieces. It was then weighed, and four pounds fifteen ounces was allowed for each quartern loaf, the baker observing, that a loaf of that size, loses from ten ounces and a half to eleven ounces, while in the oven. It was then worked up, and the separate masses were laid in a row till the whole were weighed, and, on counting them afterwards, he found they were equal to one hundred and sixty-three and a half quartern loaves; but this circumstance is variable, as some flours kneaded better than others.

It should have been mentioned that the fire was kindled at two o'clock, and continued burning till near four, when the oven was cleansed from dirt and ashes.

The bread being put in, the oven was close stopped, till seven o' clock, when it was opened, and the bread withdrawn.

TO MAKE ROLLS, AS PRACTISED BY BAKERS.

The flour was sifted and mixed in the same manner as was done for the bread; at half past six o'clock they were moulded up, and a slit was cut along the top of each with a knife; they were then set in rows, on a tin, and placed in a proving oven to rise, till a quarter

* This practice, though general, ought to be discarded, as it produces obstinate costiveness, and the late Dr. Lake, in his treatise on the diseases of the viscera, asserts from his own knowledge, that jalap is often introduced to counteract the astringent quality of the alum. It it proper to add, that there is a very heavy penalty on this species of adulteration.

quarter of an hour before eight o'clock, when they were drawn, and set in the oven, which was closed as before; at eight o'clock they were taken out, and were slightly brushed over with a buttered brush, which gave the top crust a shining appearance, they were then covered up with flannel till wanted for sale.

TO MAKE FRENCH ROLLS.

Put a peck of flour into a kneading trough, and sift it through a brass wire sieve, then rub in three quarters of a pound of butter, and, when it is intimately blended with the flour, mix up with it two quarts of warm milk, a quarter of a pound of salt, and a pint of yeast; let these be mixed with the flour, and a sufficient quantity of warm water to knead it into a dough: it must then stand two hours to prove, when it may be moulded into rolls or bricks, which must be placed on tins and set for an hour in the prover. They must then be put into a brick oven for twenty minutes, and when drawn, rasped.

TO MAKE HOUSEHOLD BREAD, AS PRACTISED BY THE BAKERS.

Household bread undergoes the same preparation as wheaten bread, with this difference, that, instead of being made with fine flour, it is made of an inferior sort, called seconds flour, and the loaves instead of being marked with a W, are marked with an H; and bakers neglecting this distinction are liable to be fined; but like all good laws, it is some times evaded, by mixing the two flours together, and making the mixture into white bread, which is coloured with chalk or whiting, that the fraud may not be detected.

TO MAKE STANDARD WHEATEN BREAD.

Send a quarter of wheat to the mill, and let it be so ground that the flour shall weigh three fourths of the wheat from whence it was made, without any mixture or addition; then let it undergo the same preparation as that for wheaten bread, observing before the loaves are put into the oven, to mark them with the letters S W.

SUBSTITUTES FOR WHEATEN BREAD.

Since wheat forms our principal support, it is not to be wondered, that from time to time attempts have been made to discover a substance that would altogether, or in part, supply its place; and we feel much pleasure in saying, that the enquiry has been so far successful, that were the public to avail themselves in times of scarcity, of the advantages of these discoveries, it would very much contribute to lessen the consumption, and consequently the price of this staff of life.

The subject of this enquiry is at this time more particularly important, owing to the excessive high, and increasing price of wheaten-flour; and we most earnestly recommend to all, at least to avail themselves of the advantages which these experiments, which we are about to lay before them may afford, and to such as have leisure for the farther prosecution of a subject, to the importance of which, every other pursuit seems trifling.

The Board of Agriculture, anxious to know what quantity of flour each of the following sorts of grain would produce, caused a bushel of each sort to be purchased, and ground for their inspection, the results of which are as stated in the following tables.

One bushel of

Grain.	Weighed.	Weight of Flour.	Weight of Bran.
Barley	46lb.	38lb-10½oz.	5lb. 10½oz.
Buck Wheat	46¼	38..9	5..5
Rye	54	43..0	9.. 5½
Maize	53	44..0	8..10½
Rice	61¼	60..0	....
Oats	38¼	23..5	13..10½
Beans	57¼	43..5½	12.. 0
Pease	61¼	47..0	12.. 5
Potatoes	58	8 ..0	....

This estimate was made when the price of the several articles were as follows:—in the first column is the price of the grain, and in the second the price per pound of each kind of flour, the bran is generally considered as an equivalent for the grinding.

Grain.	Price per bushel.	Flour per pound.
Barley	5s...6d.	0s...1½d.
Buck Wheat	6 ..0	0 ..1¼
Maize	7 ..6	0 ..2
Rye	6 ..6	0 ..1¼
Rice	23 ..0	0 ..4
Oats	4 ..0	0 ..1
Beans	5 ..6	0 ..1½
Peas	10 ..0	0 ..3¼

Barley is employed as a part of diet in many parts of this country. Next to wheat, it is the most profitable of the farinaceous grains, and when mixed with a small preparation of that flour, makes as light, and as good bread as that grain, and infinitely cheaper; but bread made of barley flour is not so spongy, and feels heavier in the hand than wheaten. But this is no proof that it is not equally nutricious, as it is a well known fact, that thousands of the healthiest and most robust peasants of this country, never taste any other bread than that prepared from this grain.

It is necessary to remark, that in grinding barley to flour, the French stones should be used in preference to any other, as experience has ascertained that they produce flour of a brighter colour, and preserve what the bakers term, the life of the flour; and they are of opinion, that barley ground with these stones, raises the bread to the greatest height it can possibly be brought to.

No

No chemical analysis has yet been made to ascertain the composition of barley flour, but we have every reason to believe, that it is either destitute of the glutinous substance of wheat, or possesses it in a very trifling degree. With respect to the starch, on which its nutricious properties principally depend, that consists of the most considerable part of the grain: and there can be no doubt, from the facility with which it is converted into malt, that the saccharine extract is more abundant than in wheat. Supposing this statement to be correct, whoever requires a light porous bread to be made from barley, will find it necessary either to add some of the glutinous substance of wheat, which may be obtained at the starch manufactories; or what is commonly practised, a certain proportion of fine wheaten flour. Other substances are sometimes made up with barley into bread, but that bread must necessarily be heavy, unless it contains this peculiar gluten, without which, no light porous bread can be made. To remedy this defect, it is always best to set the sponge with wheat flour altogether, as barley flour does not ferment readily with yeast, and add the barley flour, when the dough is going to be made. Bread made in this way requires to be kept a longer time in the oven than wheaten bread, and the heat should also be somewhat greater.

TO MAKE BARLEY BREAD, BY SIR J. CALL.

Take forty-four pounds of barley meal, and let it be kneaded up, into dough, with water, yeast, and salt, and divided into eight loaves; when thoroughly baked, drawn out of the oven, and left two hours to cool, they will weigh about sixty pounds,

This barley bread is very good, and is such as is eaten by many of the farmers in Devon and Cornwall, by most of the labourers in husbandry, and by almost all the miners, even when wheat was much more plentiful, and not above half the price it was during the season of scarcity.

TO MAKE MIXED BREAD, BY DR. PENNINGTON.

Take fourteen pounds of barley flour, and the same quantity of pulp of potatoes, which is prepared by paring the potatoes, and then grating them down into an earthern vessel, and pouring water upon them. This must be poured off in about three hours, as it has a disagreeable earthy taste, and fresh water poured on, which, when changed, will be found nearly clear and insipid. The pulp must then be taken out and put in a sieve, that the water may drain from it, and when tolerably dry, it will be fit to mix with the flour. Let it be kneaded up into a dough with warm water, and a sufficient quantity of yeast and salt, and after standing the usual time to prove, they will be found to weigh twenty-eight pounds.

Another method of making mixed bread, is, to take two pecks of barley flour, and one peck of rice flour. Let these be kneaded up into a dough, and baked in the usual way, when they will be found to produce a very good and nourishing bread.

TO MAKE MIXED BREAD, FROM THE REPORTS OF THE BOARD OF AGRICULTURE.

Take four bushels of wheat ground to one sort of flour, extracting only a very small quantity of the coarser sort of bran. Add three bushels and a half of barley flour, bolten through a twelve or fourteen shilling cloth; then mix them up into a dough, in the usual manner, with salt, yeast, and warm water, and let it be divided into half peck loaves, and put into the oven, which must be made hotter than for wheaten bread. Let them remain in three hours and a half, when it will be found a very nourishing good bread.

Buck-wheat is so little used as an aliment in this country, that there is little opportunity of studying its effects; but, from all appearance, it has the common quality of the other species of grains. A considerable quantity is annually grown in Norfolk; but, it is principally consumed by swine and poultry, both of which it fattens quick and well. In France, particularly in Britany it is much used, and is there accounted a very wholesome and nourishing grain; and when properly ground, makes an agreeable and nourishing bread.

A peculiarity attends the management of this grain at the mill, which, if not attended to, the flour will not make a bread that is any way palatable. The following account of the mode of using and grinding buck-wheat, in Britany, was communicated to the Board of Agriculture, by an intelligent emigrant from that province. In the first place, if the heat of the sun is not sufficiently powerful to cure it properly, it must be dried in a kiln, and then as much is sent to the mill as is wanted for a fortnight, or three weeks at the farthest. The miller is careful to grind, in the first instance, so as to separate the meal and the bran from the black, hard, and triangular husk, without grinding it down; for this purpose, he places the stones in such a manner as only to press lightly, which, takes off the husk, a process termed running it through the mill-stones. The farinaceous part of the grain is then easily separated from the husk, by winnowing, This process being over, he proceeds with his grinding and dressing, the same as with any other grain.

TO MAKE BUCKWHEAT BREAD, FROM THE REPORTS OF THE BOARD OF AGRICULTURE.

Take a gallon of water, set it over the fire, and when it boils, let a peck of the flour of buck-wheat be mixed with it by degrees, keep it constantly stirred, so as to prevent any lumps from being formed, till a thick batter is made like that of Scotch or Yorkshire pottage. Some salt must be added, then set it over the fire, and allow it to boil an hour and a half. The proper proportion for a cake is then to be poured into an iron kettle that hangs over the fire, and baked, taking care to turn it frequently, lest it should burn.

TO MAKE MIXED BREAD FROM THE REPORTS OF THE BOARD OF AGRICULTURE.

Take a peck of the flour of buck-wheat, mix it, and boil it with water, as before described. While this process is going on, let a peck of wheat flour be put in a kneading trough, and rather more than the usual proportion of yeast mixed with it. When the batter is boiled enough, it should be taken off the and fire, when cooled to the degree of blood heat, should be poured into the trough, with the wheaten flour and yeast; the whole should now be well kneaded, and stand two hours to prove, when it is to be divided into loaves, and baked, remembering to keep it in the oven rather longer than wheaten bread.

Bread made in this manner can be safely recommended, as certainly, at least not less nutricious, and perhaps more palatable when properly baked, than any other; but to have it light and good, requires some experience, otherwise it will be compact and heavy.

Rye is a grain, whose cultivation is not much encouraged in this kingdom, but, in the northern parts of Europe it is much used, and considered as nourishing food. Bread made of this grain alone, is of a dark colour, and sweetish taste. In some parts of this kingdom, a mixture of rye and wheat is reckoned an excellent bread, and is esteemed more wholesome than that which is made from wheat alone, and as it is well known to be a nutricious grain, its consumption cannot be too strongly recommended.

TO MAKE MIXED BREAD.

Take a peck of wheat flour, and the same quantity of rye flour: let these be kneaded together with a sufficient quantity of yeast, salt, and warm water. It should be covered up warm for two hours, to ferment, and then divided into loaves, and baked in the usual way.

TO MAKE A GOOD HOUSEHOLD BREAD, FROM THE REPORTS OF THE BOARD OF AGRICULTURE.

Suppose a bushel of rye to weigh sixty pounds, to that add fifteen pounds of rice. This, when ground down, and only the broad bran taken out, which seldom exceeds five pounds for that quantity, is thus prepared for household use:

Take fourteen pounds of this flour, a sufficient quantity of yeast, salt, and warm water, and let it be made up and baked in the usual way, and it will be found to produce twenty two pounds weight of bread, which is a surplus of three pounds and a half in fourteen pounds, over what is usually produced in the common process of converting household wheat flour into bread.

Respecting maize, no direct experiments have yet been made to ascertain its constituent parts: as it possesses but little sweetness, and does not ferment with yeast, so as to make a light bread; we may conclude, that it either wants the saccharine principle, and the glutinous substance, which render wheat so susceptible of fermentation, or that it possesses them in a very small degree; at the same time it affords an abundant quantity of starch of the best quality, the imperfections of which may be easily corrected by adding a proportion of wheat flour to it, when it may be fermented into a perfect bread.

Rice is a hard grain with a coarse white husk, somewhat resembling barley, only whiter, and much harder. From the tedious and defective manner in which it is cleaned from the husk, the Board of Agriculture are of opinion that it might be obtained at a much lower price if imported with the husks on; for from the perfection of our machinery, it might be cleaned at a much less expense than by manual labour.

The art of making bread from rice, though much spoken of, seems to be very little known. When the rice is reduced to flour take as much of it as you think necessary and put into a kneading trough; at the same time heat some water in a saucepan, and having thrown into it a few handfuls of rice, let them boil together for some time; the quantity of rice must be such as to render the water very thick and glutinous. When this glutinous matter is a little cooled, it must be poured upon the rice flour, and the whole well kneaded together, adding thereto a little salt, and a proper quantity of yeast. The dough must then be covered with warm cloths, and suffered to stand till it rises. During the fermentation, this paste, which, when kneaded, must have such a proportion of flour as to render it pretty firm, becomes so soft and liquid, that it seems impossible it should be formed into bread, and must be treated as follows.

When the dough is rising, the oven must be heated, and when it is of a proper degree of heat, take a stew-pan of tin or copper, tinned, to which is fixed a handle of sufficient length to reach to the end of the oven. A little water must be put into this stew-pan, and then it is to be filled with the fermented paste, and covered with cabbage leaves or a sheet of paper. When this is done, the stew-pan is to be put into the oven, and pushed forward to the part where it is intended the bread shall be baked: it must then be quickly turned upside down. The heat of the oven acts upon the paste in such a way as to prevent its spreading, and keeps it in the form the stew-pan has given it.

In this manner pure rice bread may be made: it comes out of the oven of a fine yellow colour, like pastry which has yolks of eggs in it. It is as agreeable to the taste as to the sight, and may be used like wheat bread to eat or put in broth.

TO PREPARE BREAD FROM RICE, BY THE MATRON OF THE FOUNDLING HOSPITAL

Boil a quarter of a pound of rice till it is quite soft: then put it on the back part of a sieve to drain, and when it is cold, mix it up with three quarters of

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a pound of flour, a spoonful of yeast, and a small table-spoonful of salt. Let it stand for three hours, then knead it up, and roll it in about an handful of flour, so as to make the outside dry enough to put in the oven. About an hour and quarter will bake it, and it will produce one pound fourteen ounces of good white bread, but it should not be cut till it is two days old.

To make mixed bread.—Take half a peck of rice flour, and one peck of wheat seconds flour, mix them together, and knead the dough up with a sufficient quantity of salt, yeast, and warm water, then divide it into eight loaves and bake it.

To make mixed bread.—Take a peck of rice, boil over night till it becomes soft, then put it in a pan, and by the morning it will be found to have swelled very much. A peck of potatoes, should now be boiled, skinned, and mashed into a fine pulp, and while hot, be well kneaded up with the rice, and a peck of wheat flour; a sufficient quantity of yeast and salt should now be added, and the dough left in the kneading trough two hours to prove; it is then to be divided into loaves and baked in the usual way.

To make oat bread.—Take a peck of oatmeal and an ounce of salt, stir them up into a stiff paste with warm water, roll it out into thin cakes, and bake them in an oven or over the embers.

This kind of bread is much used in Scotland, among the lower order of people, who, from long custom, prefer it to the best wheaten bread. In some cottages it undergoes the acetous fermentation, and is thereby rendered lighter and more easy of digestion; but the generality of people merely soften their oatmeal with water, and bake it over the fire.

TO MAKE MIXED BREAD, BY DR. R. PIERSON.

Take a peck of oatmeal, the same quantity of seconds flour, and half a peck of boiled potatoes, skinned and mashed, let them be kneaded up into the dough, with a proper quantity of yeast, salt, and warm milk; it should then be made up into loaves, and put into the oven, where it is to remain three hours.

The bread thus prepared rises well in the oven, is of a light brown colour, and by no means unpleasant flavour: tasting so little of the oatmeal as to be taken, by those who are unacquainted with its composition, for barley or rye bread. It is sufficiently moist, and if put in a proper place, keeps well for a week. Bread made in this way is about eightpence half-penny a peck cheaper then wheaten bread; which in large families, will, at the years end amount to a very considerable saving if it was substituted for it.

To make mixed bread.—Take one peck of oatmeal, and the same quantity of rice flour, let these be kneaded up with a sufficient quantity of warm milk, yeast, and salt, and after standing a proper time to prove, will be found a very palatable and wholesome bread.

Beans, when dry and husked, are readily broke down into a fine flour of the same nature and properties as the meal of other grains; they have a sweeter taste, and afford, by proper treatment, a starch equal to that of wheat; the flavour of bean flour is disagreeable; but if steeped in water before it is used, this unpleasant taste will then be hardly perceived.

To make bean bread.—Take a quarter of a peck of bean flour, and a little salt, mix them up into a thick batter with water, then pour a sufficient quantity to make a cake into an iron kettle, and bake it over the fire, taking care to turn it frequently lest it should burn.

TO MAKE MIXED BREAD, FROM THE REPORTS OF THE BOARD OF AGRICULTURE.

Send a bushel of good dry beans to the mill, let the husks be taken off, and then grind the meal into a fine flour, which if good, will produce a full bushel of this flonr. Let a peck be soaked for three days in a pan of water, changing the water every day to take off its disagreeable flavour; then pour the water clear off, and put the meal into a sieve to drain; while this is drying, put a peck of w. eat flour in the kneading trough, and mix it up with some salt and yeast. After it has properly fermented, knead the bean flour with it into a dough, and after it has stood a sufficient time to prove, let it be divided into loaves and baked.

To make pea bread.—Take a peck of the flour of peas, the like quantity of oatmeal, and two ounces of salt; knead them up into a stiff paste, with warm water, let it be rolled out into thin cakes, and baked over the embers.

To make mixed bread.—Take four pounds of pea flour, steep it in water, as directed for beans, then knead it up with four pounds of potatoe flour, and double that quantity of seconds wheat flour, which has been previously fermented with yeast, and a proper quantity of salt, and let the dough stand to rise, when it must be divided into loaves, and baked.

To reduce potatoes to flour.—Put a bushel of kidney potatoes into a large tub, and clean them from the dirt, afterwards scrape them clean with a brush, and let them be rasped into a pulp, on a bread grater, into a hair sieve, that is placed over a broad deep pan. Let some water be poured occasionally, by one person, over the pulp, while another stirs it with his hand; the water in its passage, carries the starch with it, which is deposited at the bottom of the pan. After standing a night, the water is poured off, and the starch remaining behind is taken out and put into conical baskets like those used for salt, covered with cap paper, and hung in a stove to dry by a gentle heat. It is then ground in a hand mill, and passed through a fine lawn sieve, when it will have the exact appearance of starch, be of a beautiful white colour, and is then ready to make into bread. This powder, with the addition of a small quantity of gum tragacanth in

 powder,

powder, is in universal request, as a light nourishing food for invalids, and, is sold in the shops under the name of Indian Arrow Root. A bushel of potatoes that weighs sixty pounds, if they are mealy ought to produce, in this way, eight pounds of flour at least: and suppose an acre of good land, well managed, would yield three hundred bushels, near a ton and a quarter of this flour might be produced from it.

To make potatoe bread.—Pare one peck of potatoes, put them into a proper quantity of water, and boil them till they are reduced to a pulp, then beat them up fine in the water they are boiled in, and knead them with two pecks of wheat flour, with a sufficient quantity of yeast and salt, into a dough: cover it up, and allow it to ferment for two hours or upwards, according to the state of the weather; then make it up into loaves and bake them.

To make potatoe bread.—Choose the most mealy sort of potatoes, boil and skin them, take twelve pounds, break and strain them through a very coarse sieve of hair, so as to reduce the roots as nearly as possible to flour. Mix it up well with twenty pounds of wheaten flour; of this mixture make and set the dough exactly in the same manner, as if it were wholly wheaten.

TO MAKE POTATOE BREAD, BY P. COLQUHOUN ESQ.

Take three pounds of potatoes, put them into a skillet with cold water, hang it at a distance over the fire, so that they may not boil; then skin and mash them, and whilst warm, bruise them with a spoon, put them into a dish before the fire to evaporate the moisture, stirring them frequently, that no part may grow hard; when dry, take them up and rub them as fine as possible between the hands, then add nine pounds of wheaten flour, and with a sufficient quantiof yeast, and salt, knead it up as other dough. After laying a little while to prove, it should be made into small loaves and baked in a hot oven.

To make acorn bread.—Take a quantity of acorns, fully ripe, deprive them of their covers and beat them into a paste, let them lie in water a night, and then press it from them, which deprives the acorns entirely of their astringency. Then dry and powder the mass for use. When wanted, knead it up into a dough with water, and roll it out into thin cakes, which are to be baked over the embers.

TO MAKE CHESNUT BREAD, BY M. PARMENTIER.

Take a peck of horse chesnuts, peel the skins off them, let them be bruised into a paste, dilute the mass with water, which destroys their astringency, and strain them through a sieve; a milky liquor is thus separated, which, on standing, deposits a fine white powder: this, on being dried and ground into flour, is found to be without smell or flavour. It is then made up, sometimes by itself, and not unfrequently with an equal portion of wheat flour, into a paste, with warm milk, and a little salt, and when baked makes very good and palatable bread.

TO MAKE TURNIP BREAD, BY J. SANDS, ESQ.

Boil the turnips till they become soft enough to mash, and press the water well out of them; then mix them with an equal weight of wheat meal and make the dough in the usual way, taking care to let the loaves remain rather longer in the oven than for wheaten bread.

Sea biscuit is a sort of bread, much dried, to make it keep on long voyages. It was formerly baked twice, or oftener, and prepared six months before the embarkation.

The process of baking biscuit, for the British navy, is as follows:—and it is equally simple and ingenious. The meal, and every other article being supplied with much certainty and simplicity, large lumps of dough, consisting merely of flour and water mixed up together: and as the quantity is so immense, as to preclude the possibility of kneading it by hand, a man manages, or as it is termed, rides a machine, which is called a horse. This machine is a long roller, about four or five inches in diameter, and about seven or eight feet in length; it has play to a certain extension, by means of a staple in the wall, to which it is connected by means of a swivel making its action like the machine, by which they cut chaff for horses. The lump of dough being placed exactly in the centre of a raised platform, which is placed directly under the horse; the man sits upon the end of the machine, and literally rides up and down throughout its whole circular direction till the dough is equally indented; and this is repeated till the whole is sufficiently kneaded: at which times, by the different positions of the line, large or small circles are described, according as they are near to, or distant from the centre of motion of the horse.

The dough, in this state, is handed over to a second workman, who slices it with a prodigious knife, and it is then in a proper state for these bakers, who attend the ovens; those are five in number; and their different departments are as well calculated for expedition and correctness, as the making of pins, or other mechanical employments. On each side of a large table, where the dough is laid, stands a workman: at a small table near the oven, stands another; a fourth stands by the side of the oven, to receive the bread; and a fifth to supply the peel. By this arrangement, the oven is as regularly filled: and the whole exercise performed in as exact time, as a military revolution. The man at the further side of the large table, moulds the dough, having previously formed it into small pieces, till it has the appearance of muffins, although thinner, and which he does two together, with each hand: and as fast as he accomplishes this task, he delivers his work over to the man on the other side of the table, who stamps them with a docker, on both sides with a mark. As he rids himself of this work, he throws the biscuits on the smaller table, next the oven, where

where stands the third workman, whose business is merely to separate the different pieces into two, and place them immediately under the hand of him who supplies the oven, whose work of throwing, or rather chucking the bread upon the peel, must be so exact, that if he looked round for a single moment, it is impossible he should perform it correctly. The fifth receives the biscuit on the peel, and arranges it in the oven; in which duty he is so very expert, that though the different pieces are thrown at the rate of seventy in a minute, the peel is always disengaged in time to receive them separately.

As the oven stands open during the whole time of filling it, the biscuits first thrown in, would be first baked, were there not some counteraction to such an inconvenience. The remedy lies in the ingenuity of the man who forms the pieces of dough; and who, by imperceptible degrees, proportionally diminishes their size, till the loss of that time, which is taken up during the filling the oven, has no more effect to the disadvantage of one of the biscuits, than to another.

So much critical exactness, and neat activity occur in the exercise of this labour, that it is difficult to decide whether the palm of excellence is due to the moulder, the marker, the splitter, the chucker, or the depositor; all of them, like the wheels of a machine, seeming to be actuated by the same principle. The business is to deposit in the oven seventy biscuits in a minute; and this is accomplished with the regularity of a clock; the clack of the peel, during its motion, in the oven operating like the pendulum.

The biscuits, thus baked, are kept in repositories, which receive warmth from being placed in drying lofts over the ovens, till they are sufficiently dry to be packed into bags, without danger of getting mouldy; and when in such a state, they are then packed into bags of a hundred weight each, and removed into storehouses, for immediate use.

The number of bakehouses belonging to the victualling office, at Plymouth, are two, each of which contains four ovens, which are heated twenty times a day, and in the course of that time bake a sufficient quantity of bread for 16,000 men.

The granaries are large, and well constructed. When the wheat is ground, the flour is conveyed into the upper stories of the bakehouse, whence it descends through a trunk in each, immediately into the hands of the workmen.

The bakehouse belonging to the victualling office, at Deptford, consists of two divisions, and has twelve ovens, each of which bakes twelve shoots daily; the quantity of flour used for each shoot, is two bushels, or 112 pounds, which baked, produce 102 pounds of biscuit. Ten pounds are regularly allowed on each shoot, for shrinkages, &c. The allowance of biscuit in the navy is one pound for each man per day, so that one of the ovens at Deptford, furnishes bread daily for 2,040 men.

ON THE PREPARATION AND PRESERVATION OF YEAST.

To make yeast from potatoes, by J. Kirby, Esq.

Boil potatoes of the mealy sort, till they are thoroughly soft, skin and mash them very smooth, and put as much hot water on them, as will make a mash of the consistency of common beer yeast, but not thicker. Add to every pound of potatoes, two ounces of treacle, and when just warm, stir in for every pound of potatoes, two large spoonfuls of yeast. Keep it warm till it has done fermenting, and in twenty-four hours it will be fit for use. A pound of potatoes will make near a quart of yeast, and will keep three months. This yeast has been found to answer the purpose so well, as not to be able to distinguish the bread made with it, from brewers yeast.

TO MAKE YEAST, BY DR. LETSOM.

Thicken two quarts of water, with four ounces of fine flour, boil it for half an hour, then sweeten it with three ounces of brown sugar; when almost cold, pour it with four spoon-fulls of bakers yeast into an earthen jug, deep enough for the fermentation to go on without running over; place it for a day over the fire, then pour off the thin liquor from the top, shake the remainder, and close it up for use, first straining it through a sieve. To preserve it sweet, set it in a cool cellar, or hang it some depth in a well. Keep some of this to make the next quantity wanted.

TO MAKE YEAST, AS PRACTISED AT EDINBURGH, BY THE HON. CAPTAIN COCHRANE.

Take two ounces of hops, boil them for an hour in two gallons of water, and while boiling hot, scald ten pounds of flour, and stir it very well into a paste; do this about eleven o'clock in the forenoon, let it stand till six o'clock in the evening, then add about a quart of yeast, to forward the fermentation, and mix them well together. Next morning add as much more flour and water sufficient to make it into a dough, and in the afternoon it will be fit for setting sponge and baking. Reserve always a piece of old dough to mix with the new batch, instead of yeast, which is necessary, only the first time to hasten the process.

THE METHOD OF MAKING YEAST, BY MR. GILLISPIE, A BAKER AT LEITH, WHO USES IT IN PREFERENCE TO DISTILLERS YEAST.

In the first place you must have a boiler, cooler, vats, and all the apparatus that would be necessary for a small brewery. Then take four bushels of the best malt, ground as for beer, and mash it in the same manner the brewers do, with sixty-two gallons of water, at the temperature of 180°; let it be close covered up for two hours, then draw the liquor clear off, and pour on the same quantity of water upon the grains a second time, at nearly the boiling point; let this stand an hour, then draw it off, and mix it

in

in the coolers with the first wort, and when it is about blood warm, add four English quarts of yeast, to produce the fermentation, and after it has began to ferment the first time, (the froth running over into a receiver for the purpose,) throw it back again, and when it has fermented again, throw it back a second time, and it will after the third fermentation, be fit for use, as will be perceived by its being of the thickness that good yeast ought to be. Four bushels of malt, made in this way, produces about twenty-four quarts of yeast; it is an expensive and troublesome way of procuring it, but Mr. Gillispie finds, that a quart of it will go as far as a gallon of distillers yeast.

DESCRIPTION OF THE BAKE HOUSE.

The bake house is a manufactory where bread is made for sale. In order to render it convenient, it should be attached to the dwelling house, and have an inner door opening into the kitchen, and likewise an outer door opening into a small yard, in which there ought to be a well or pump, and also, a shed for piling away faggots. The room should be large and commodious, and the floor laid with stones or tiles. On one side should be erected a dresser or counter, with suitable shelves about it: on another a kneading trough, about seven feet long, three feet high, two and a half broad at top, and sixteen inches at the bottom, with a sluice board to pen the dough up at one end, and a lid to shut down like that of a box. On the third side a copper that will contain from three to four pails of water should be erected, which is far preferable to the filthy custom of heating the water in the oven; and on the fourth side the oven should be placed. A bakehouse built upon this plan will, perhaps, be as commodious as art can render it; but of late years, an alteration has been made in the manner of fitting up the oven and copper, that both may be heated with the same fire.

In order to comprehend the usefulness of this improvement, it will be necessary to state that an oven, built upon the old principle, is usually of an oval shape; the sides and bottom of brick, tiles, and lime, and arched over at top with a door in front; and, at the upper part, an enclosed closet with an iron grating, for the tins to stand on, called the proving oven. To heat these ovens, the faggots are introduced and burnt to an ash: it is then removed, and the bottom cleaned out. This takes up a considerable space of time, during which period a great deal of heat escapes. A still farther length of time is necessary for putting in the bread, and unless much more fuel is expended than is really necessary, in heating an oven upon this principle, it gets chilled before the loaves are all set in, and the bread is, therefore, liable to fall; a circumstance that unavoidably renders it heavy.

To remedy this inconvenience, many intelligent bakers have, within these few years past, had their ovens built upon a solid base of brick and lime, with a door of iron, furnished with a damper to carry off the steam as it rises. On one side of it is placed a fire with a grating, ash-hole, and iron door, similar to that under a copper, with a partition to separate it from the oven, and open at one end. Over this is erected a middling-sized copper with a cock at the bottom, and on one side of it is placed the proving oven; the whole being faced with brick and plaster.

When this oven is required to be heated, the copper is filled with water, and the fire being kindled with coals, the flame runs round the oven, in a circular direction, and renders it as hot as if heated with wood, without occasioning the least dirt or ill smell; and the smoke escapes through an aperture, which passes into the kitchen chimney. When the coal is burnt to a cinder, there is no necessity to remove it, as it prevents the oven from cooling while the bread is setting in, and keeps up a regular heat till the door is closed. The advantages of an oven built upon this construction, are so considerable, independent of the great saving in fuel, that when its principles come to be generally known amongst bakers, there is no doubt but that they will prefer it to those heated with wood.

In great bakehouses, where rolls and French bread are wanted every half hour, from eight o'clock in the morning till eleven, the perpetual oven invented by Count Rumford, will be found particularly useful; more especially if they are called upon to bake meat, puddings, and pies, at different hours in the afternoon. At present, after they are done, they are obliged to keep them warm in the proving oven; but the crust always becomes heavy, and the meat soddened: but in one of these perpetual ovens, they might have such things baked, at the time their customers required them, without putting themselves to any material inconvenience, and besides, there would be this farther advantage attending the baking, that the effluvia arising from the different sorts of meal would never be mixed, and occasion an ill taste, as it now does in the great ovens. The following is the description given of it by the Count, with the manner of using it.

In the centre of a circular, or, rather, a cylindrical mass of brick work, about eight feet in diameter, which occupies the middle of a large room on the ground floor, I constructed a small, circular, closed fire place, for burning either wood, coals, turf, or peat. The diameter of the fire place is about eleven inches; the grate being placed about ten inches above the floor, and the top of the fire place contracted to about four inches. Immediately above this narrow throat six separate canals (each furnished with a damper, by means of which its opening can be contracted more or less, or entirely closed), go off horizontally, by which the flame is conducted into six separate sets of flues, under six large plates of cast iron, which formed the bottom of six ovens on the same level, and joining each other by their sides, which are concealed in the cylindrical mass of brick work. Each of these plates of cast iron, being in the

the form of an equilateral triangle, they all unite in the centre of the cylindrical mass of brick work; consequently the two sides of each, unite in a point at the bottom of it, forming an angle of sixty degrees. The flame, after circulating under the bottoms of these ovens, rises up in two canals, concealed in the front wall of each oven, and situated on the right and left of its mouth; and after circulating again in similar flues, on the upper flat surface of another triangular plate of cast iron, which forms the top of the oven, goes off upwards, by a canal furnished with a damper, into a hollow place, situated on the top of the cylindrical mass of brick-work, from which it passes off in an horizontal iron tube, about seven inches in diameter, suspended near the ceiling, into a chimney, situated on one side of the room. These six ovens, which are contiguous to each other in this mass of brick-work, are united by their sides, by walls made of tiles, about an inch and a half thick, and ten inches square, placed edgwise, and each oven having its separate canal, furnished with a register, communicating with the fire place. Any one, or more of them, may be heated at the same time without heating the others, or the heat may be turned off from one of them to another, in continual succession, and by managing matters properly, the process of baking may be uninterrupted. As soon as the meat pies, or puddings are drawn out of one oven, the fire may be immediately turned under it, to heat it again, while that from under which the fire is taken, is filled with other dishes and closed up.

A detail of the utensils in use, in a bakehouse, may appear uninteresting: and some of our readers may think it perfectly unnecessary; but those bakers who are solicitous to have good bread, would deem the subject incomplete, without noticing them. The following are the most useful and indispensible requisites.

The seasoning tub.—This is of the size and shape of the common wash tub, and is intended for mixing the yeast, salt, and water together, before the sponge is set.

The seasoning sieve.—This is a common sized hair sieve, and is used for straining the mixture through, that is prepared for setting the sponge.

The warming pot.—This is a large copper pot, lined with tin, capable of holding two pails full of water. It is filled and set in the oven to warm, before the baker sets his sponge. These are not in universal use, as some people use earthern ones; but this mode of warming the water, however objectionable, is daily practised by the most respectable bakers in the metropolis.

The brass-wire sieve.—This is a large round sieve covered with a sheet of very fine wove, brass-wire; its use is not only to sift the flour before it is kneaded, but also to detect any lumps, or other impurities that may be contained in it.

The pail.
The bowl.
The spade.

These are requisite for a variety of purposes, and are of the same kind as are in common use.

The salt-bin.—This is a bin with a lid to it, similar to a corn-bin. It should hold two sacks of salt, and is usually placed near the oven.

The yeast-tub.—This is a common six-gallon cask, with a large bung-hole, and cover, and is used for preserving the yeast.

The dough-knife.—This is usually of the size of a large carver, with a round point and blunt, like a painters pallet knife. Its use is to cut the dough, when the baker is kneading it, before he throws it over the sluice board. It is also used when the bread is weighed, to divide the different portions before they are put in the scales.

Scales and weights.

The scraper.—This is a small scraper, like a garden hoe, fixed in a short wooden handle. Its use is to scrape the sides and bottom of the trough, to prevent the dough from adhering and drying there.

Marks.—These are four large tin letters, fixed in a wooden handle. One is marked W. another H. a third S. W. and the fourth M.; and every loaf, wheather wheaten, household, standard wheaten, or mixed bread, is obliged in conformity to act of parliament, to be marked with one of those instruments, before it is put into the oven.

The rooker. This is a long piece of iron, in shape somewhat resembling the letter L, fixed in a wooden handle.—Its use is to draw out the ashes from all parts of the oven to the mouth.

The hoe.—This is a piece of iron, similar to a garden hoe, fixed in a handle, partly wood, and partly iron. Its use is to scrape up such dust and loose ashes as escaped the rooker.

The swabber.—This is a common pole, about eight feet long, with a quantity of wet netting fastened to the end. Its use is to clean out the bottom of the oven, after the ashes have been removed, previous to setting in the bread.

Peeles.—There are usually four peeles kept in a bakehouse, viz. the quartern peele, to set in the quartern loaves: the half quartern peele, for the half quartern loaves; the drawing peele, for drawing out the bread; and the peele for placing and removing the tins. The quartern peele is a pole about eight feet long, with a wooden blade: about a foot wide and sixteen inches long, fixed at the end with strong screws. The half quartern peele is of the same kind; about half the length, and much smaller. The drawing peele is a strong pole, ten feet long, with a blade, thicker, broader, and longer than the others; the peele for setting in the tins, has a strong blade of iron, instead of wood, which is fixed with screws into the handle.

Tins.—These are iron plates of different sizes.

The most usual are about an eighth of an inch thick, two feet wide, and three feet long. The rolls, pies, and puddings are put upon these tins and then the baker runs the blade of the peel under each of them, and places them into any part of the oven, with the utmost facility.

Flannels.—These are squares of coarse flannel, and are used for covering up the bread, and rolls after they are taken out of the oven.

The rasp.—This is a large, coarse, broad, flat, steel file, with a wooden handle that runs over the back. Its use is for rasping the burnt crust off the bread, and a finer one is kept to rasp the French rolls.

BASKET-MAKING.

The ancient Britons have been celebrated for their skill in the manufacture of baskets, from the time of the Romans; and so much were the baskets of this country valued by that people, that immense quantities of them were exported to Rome, where they were held in great estimation, and bore so high a price, that they are mentioned by Juvenal, among the extravagant and expensive furniture of the Roman tables, of his time.

Adde et bascaudas et mille escaria.

Add baskets, and a thousand other dishes.

That these baskets were manufactured in Britain, we learn from the following epigram of Martial:

Barbara de pictis veni bascauda Britannis,
Sed me jam mavult dicere Roma suam.
A basket, I, by painted Briton's wrought,
And now to Rome's imperial city brought.

Baskets are made either of rushes, splinters, or willows, which last are, according to their growth, called osiers, and sallows.

Osiers for white work are deprived of their bark, by means of an instrument called the brakes. This instrument has two round legs, proceeding out of, and kept asunder by a spring similar to the sheep shears; from the back of this spring projects a point or spill, serving to attach the tool to a stake. The osier being placed between the prongs or legs of the brakes is drawn through with the right hand, whilst the left hand clasping the ends of the round legs, presses the osier, and thereby bruises and strips the skin. They are afterwards completely cleaned by a common knife.

This operation is generally performed by women and children, who, as soon as the osiers are stripped, expose them to the sun and air, in order to dry them; they are then housed and kept carefully from moisture, which, if attended to, will preserve them for many years.

The same precaution is necessary for preserving osiers with their bark on, damp being equally injurious to them. When these osiers are intended to be used, they are soaked in water a few days according to their age and dryness. Osiers deprived of their bark, are assorted by the basket-maker into large and small rods, according to the work for which they are intended, the large ones serving to form the slat and skeleton of the basket, and the smaller ones for weaving the bottom and sides. For common work, such as clothes baskets, market baskets, &c. the rod is used whole, but for the finer work, as table mats, fruit and work baskets, and such like, the osier is divided into splits and skains, which words denote the different degrees of fineness, to which the rods are reduced. The splits are osiers divided into four parts, by means of a tool, called the cleaver, which is made by turning a piece of box wood to a cane, two inches long, and one and a half inches diameter at its base, this is notched in a direction from the base to the point, leaving between the notches four leaves or edges, projecting from the core or centre, so that a section, the short, or transverse way at any part from the large to the small end, would resemble crosses of different sizes, till it terminated in the point. To use it, the osier is cleft across at the large end, directly through the centre or pith, the point of the cleaver is then introduced, each leaf or edge of which falls into the cross cleft, made with the knife, and being forced on with the hand from the large to the small end of the osier, divides it into four equal parts, called splits. These are again passed through another tool, called the shave, which is in many respects similar to the common spoke-shave; but, as it is intended to be held in the left hand, whilst the split is drawn through with the right, it is fitted in a square instead of a long handle. In setting the iron, which is done by means of two screws, one end of it is kept at a greater distance from the stock than the other; the small end of the split being introduced between the iron and the stock

stock, at that end of the blade which is most distant from the stock, taking care to keep the outside or grain of the split next the wood, whilst the pith is presented to the iron, in this way it is drawn through, forcing it as it advances towards that end of the blade which is set finest, by which means it is reduced to any degree of thinness required; but as it still remains of very unequal width, it is passed through another tool called the upright.

This tool is made of a flat piece of thin steel, sharpened at each end with cutting edges, in the manner of a common chissel, the steel having been previously bent round so as to bring the ends to approach each other; in which situation they are kept by means of two screws, which act against the outside of the tool, and serve to set the tool, to cut narrower or wider, as the nature of the work requires. The whole is fixed to a wooden stock, of the same size as the shave, and when used, is held in the left hand, the fore-finger of which keeps the split flat on the stock, and presents it properly to the cutting edges of the tool, whilst it is drawn through by the right hand,

This operation reduces the splits to skains of parallel width and thickness. These are sometimes dyed of different colours, and when judiciously introduced in weaving the basket, produce a happy effect.

The following is a list of tools used by basket-makers not already described.

Knives of different sizes for cutting the osiers, &c.

Bodkins, for boring.

Leads, for keeping the basket steady whilst making, and which is only used for small light work.

The *beater*, a piece of iron of about nine inches long, shaped like the common cleaver, but without a cutting edge, its use is to beat the work close together, as the basket proceeds.

The method of making a basket of the common kind, is as follows; the workman having cut off the large ends of as many osiers as he deems necessary, and of a length somewhat more than the width of the bottom, lays them on the floor in pairs, at a little distance from each other, all ranging the same way; he then places on them two of the longest osiers with their large ends towards him, crossing the direction of the former; on the large ends of the two long osiers, he places his foot, weaving each alternately under and over the pairs of short ends, which confines them in their place, and forms, what is called the slat or slate, which is the foundation of the basket. The workman next takes the long end of one of the two rods, and proceeds to weave it under and over the pairs of short ends, all round the bottom, until he has wove in the whole of it, this is likewise done with the remaining osier, and after this is exhausted, other long osiers are wove in, until the bottom is of a sufficient size for the intended basket.

Proceed to sharpen the large ends of as many long and stout osiers as may be necessary to form the ribs, or skeleton of the basket, the sharpened ends are planted or forced between the rods of the bottom, from the edge towards the centre, and are turned up in the direction of the sides; and then other rods are wove in and out, between each of those, until the basket is raised to the intended height. To finish the edge or brim of the basket, the ends of the ribs which are now standing up perpendicularly, are turned down over each other in a manner more easily seen by inspecting a basket than described.

There remains only to add the handle; this is done by planting, or forcing down close to each other between the weaving of the sides, two or three osiers sharpened and cut to a proper length; when in their place, a hole is made through them about two inches from the brim, into which a pin is put to prevent their being drawn out, they are then covered or spliced together with skains sometimes of various colours, forming different kinds of platting on the handle.

Expert workmen produce a great variety of fancy baskets, by varying the kinds and colours of the skains, and rods they use, as well as by various different modes of working or weaving them, for the modes of colouring which, directions will be given in the second part of this work,

The following particulars relative to the propagation and culture of osiers, are copied from the "*Transactions of the Society for the Encouragement of Arts &c.*" to which they were communicated by Mr. John Phillips, of Ely, who received the silver medal.—"Since I had the honour of addressing the Society, I have made many experiments on different soils, with the view of ascertaining which are most appropriate to osier plantations; and which of the almost infinite variety of osiers, are best adapted to the different soils, but as my plantations are chiefly in the Fens, I have directed my attention more particularly to determine what species of osiers are most profitable in a black peat soil, which is the most advantageous way of planting them, and at what season of the year. It would have been of much public utility, if the basket makers had given a specific description of the kind of osiers, the planting of which they wish to be encouraged by premiums. The planters who intended becoming candidates for the reward or honours of the society, would in that case have procured those only; much expense would have been saved by other gentlemen as well as myself, and a very considerable addition would have been made in our plantations, to the stock of the best osiers which are imported from abroad. As we have no generic or specific terms, I will endeavour to give a plain vulgar account of those only which are selected by the most experienced planters in this neighbourhood. Osier, in common parlance, is a word of very indeterminate

indeterminate signification; it is certainly a species of the Salix, but admitting of many varieties. I have endeavoured to reduce them to two classes; first, those which are so called by the growers and basket makers, distinguishable by their more blunt, mealy, or downy leaf; and secondly, those that have a leaf more pointed, smooth, and green, resembling that of a myrtle. Of the first class I have nine or ten varieties, all of which I shall eradicate, save one, viz. that which is called the grey or brindled osier. It has, in common with the others, the light coloured leaf, but known by having its bark streaked with red, or blood colour. It has not been long introduced into this country. It grows vigorously, is very hardy and tough, and bleaches well. All the others of the first class, delight in a wet soil, and will flourish even in the most barren kind of peat; but they are coarse and spongy, have a large pith, are brittle, and very perishable; they are, however, sometimes used for the stouter parts of large baskets, and, unpeeled, for wine hampers. They grow quick and large, and a small number will fill the ell bunch, by which all osiers are sold; they are profitable to those growers only who live near London, or whose plantations are contiguous to water carriage. I have some acres of them; and were I to send them there by waggon which is our only mode of conveyance, they would not pay for the carriage. In time of war, when our intercourse with France and Holland has been interrupted, where they grow better sorts, they have been much resorted to, which has brought our baskets into disrepute, and lessened the demand for them in foreign markets; this, together with the advanced price of insurance, accounts for the fact, that war makes osiers in this kingdom both dear and cheap; that is, dear at the commencement for want of importation and cheap during its progress, for want of exportation, after having been manufactured into baskets and other works to which they are applied. Of the second class are, first, the Welch, both red and white; the red having the preference, and said to have been brought originally from Wales, they form an almost essential part of every plantation, as no other is fit to tie the bunches after the rods have been peeled and whitened. A bunch is formed by compressing the osiers in an iron hoop or band, of an ell in circumference; eighty bunches make a load, which four years back sold at £18. it is not now worth £12. The best land will produce a load on an acre, but half a load is not a very bad crop on bad land. The expense of weeding, renewing, cutting, and peeling, is about £5. per acre, when the business is well done; but they often go unweeded, when they are sold at a low price, to the great decay of the plantations. The Welch are also used to tie reed sheaves for thatch; they are so bitter, that cattle will not browse them, unless driven to the extremity of hunger, and rats will not touch them, although they will destroy almost every kind of bandage. They were formerly grown for the coopers, to bind their hoops; but, for this use they have long given way to the hazel; they are very tough and durable, and would rank with the best sorts for the use of basket-makers, were they of a better colour when peeled.

2d. *The West country Spaniard.*—It is supposed to have been first introduced into the west of England, from Spain. It is very different from the Spaniard, which is a species of the large willow, and used for hedging-wood and hurdles, In the Isle of Ely, it was long in high estimation, until others were introduced, supposed to be superior in some of their qualities; the bark is of a blueish grey colour, it grows stout and stately, and objects to no soil; the grower, however, urges against it, what he thinks to be a strong objection, viz.—that it produces a small crop. It bares comparatively only a few shoots on a head; this is certainly true; but what then?—then it is not so profitable. I admit it, provided only an equal number to be planted on an acre with those that bear more shoots; but why should the grower tie himself to plant an equal number of different sorts on a given quantity of land? The nursery man is governed by no such rule; and the farmer would become an object of pity, were he to sow an equal quantity of every sort of grain on an acre. The Society is bound to draw some line to prevent fraud, but the planter and farmer would be guided only by the burthen which the land is capable of bearing. My experience teaches, that an acre of land will carry of this sort, 14,000 plants with more ease than 12,000 of the best new kind.

3d. I have not been able to learn where the *new kind* originated. It is well known every where: and although it must be much older in some counties than others, it is universally called by that name. There are, however, two sorts; the other is called the last, or best new kind. The bark of the former is of a light brown colour; that of the latter resembles rusty iron, with light longitudinal stripes: it is on that account called, by some persons, the Corduroy. When the new kind was first introduced into the Isle of Ely, it soon expelled most of those of the first class; the few that are retained are used by the fishermen to make grigs, or twig tunnels, to catch eels and other fish; it still maintains considerable reputation, but yields to the last new kind, which, besides possessing most of the best properties, produces on an average, at least four shoots on the head more than any other, and it will grow well in a dry mellow soil. As its shoots are more numerous, a greater space should be attached to it, to draw nourishment from the earth, and to admit the rays of the sun and circulation of air, so necessary to the growth of every plant: 11,000 an acre is quite sufficient on good land. But the best of all, considered in a public or political view, is

4th, *The French.* Under this name the ground setter is frequently sold; and I am informed that it was

was so called from its tendency, when neglected, to direct its shoots amongst grass and weeds, parallel with, and near the ground. It is of the same quality, colour, and appearance, with the French, except that it has, at the point, a tuft formed of leaves curled inwards, which has the appearance of a small withered rose-bud. You will easily know both from all others, thus: draw them through your fist from the top to the bottom, and the leaves will snap off with the brittleness of glass. The ground-setter grows very slowly, and is rejected by the planters on that account. The French, although more luxuriant, is also comparatively of slow growth, and it requires a great number to make up the bunch; but it is exceedingly taper, pliant, close grained, tough, and durable. The basket-makers are more desirous of it than any other, as it is best suited to make the smaller and finer baskets, hats, fans, and other delicate articles. As it is much disregarded by the planters in this kingdom, the basket-makers, in times of peace, import vast quantities from France, the Austrian Netherlands (Belgium), and Holland, where it is cultivated with great success. It is singular that it should be imported cheaper than our planters can afford to grow it; the lands in France and Holland are much dearer than our fens. As an article of commerce, it deserves every encouragement that the public or individuals can give it; and if it be not so profitable to the grower, it is always of ready sale.

I have heard of another sort, which is well spoken of, called the *Red Kent Willow*; but I am doubtful whether I am possessed of it or not. We have in this neighbourhood a very hard, tough willow, of a reddish colour, of which hurdles, cribs, &c. are generally made. I planted it last year, in footsets, for the use of basket-makers; but as the experiment is now only in process, I can say nothing of its utility. I hope that those who shall hereafter become candidates for premiums, will give a description of the sorts planted by them; and of all the others that are most esteemed in their neighbourhood, perhaps some of your correspondents, who may not be candidates, will favour the public with their knowledge on the subject.

As to the most advantageous way of planting, there is some difference of opinion. The different qualities and situations of soils are not always attended to; we are often deceived by a single experiment; what may hit, or fail, one year, may be the reverse the next: it requires a diversified series of experiments to enable us to form a right judgement. My plantations of the year 1794, made on banks of soil thrown out of ditches on each side, and those made on the level ground, flourished equally well that year. It was difficult to judge of them the next year, for they had been more or less injured by the vast inundation of all the fens of the Isle of Ely, and which was not removed in many places until late in the summer; but in the third year the advantage was manifestly in favour of those which had been made on banks, or elevated beds.

We have in this district from ten to fourteen inches of vegetating soil on the surface; immediately beneath it, is a black or brown barren peat, of a loose texture. In the drought of summer, when the moisture is exhaled from the upper and more tenacious soil, the water instantly filters through the peat, and leaves the plants destitute of their best nourishment: but when the peat is thrown upon the solid earth, it will prevent the rays of the sun from penetrating to the bottom; and when the water falls in the ditches, the lower and more tenacious soil, will retain a sufficient quantity of it for the use of the plants. Care should be taken to insert the sets through the peat into this lower stratum. They will strike their radicles the first year into this more solid earth; but when the peat has been meliorated by the sun and air, and been compressed, and become more adhesive, they will strike higher in the stem, until the radicles or fibres approach the surface. It must be admitted that this is an expensive method, and lessens the quantity of land to be planted upon. To remedy this inconvenience, I lay out my land in beds or barrows, of eighteen feet wide; ditches, of nine feet wide, are dug on each side, the top of which, fourteen inches thick, is laid on the barrows; turf for fuel is then dug in the ditches, the expence of which is about 1s. 8d. a thousand; they are sold for 2s. 6d.

The beds or barrows, now consisting of about two feet and a half thick of solid earth, above the surface of the peat, are planted the following autumn, and produce good crops. When the water is sufficiently low, I cast upon these beds a fetid vegetable substance, vulgarly called bear's muck; it resembles wet shag tobacco, and lies under the peat; it is extremely useful to the plants; and although it is, in its primitive state, a perfect *caput mortuum*, when exposed sometime to the air, it putrifies, affords mucillage, and becomes a good manure. In embanked districts, subject to frequent and long inundations, two other advantages are obtained from these raised beds: the osiers are thereby removed farther from the reach of the ice, which on a thaw floats into the lower plantations, and does them much injury. When the waters are high, in the cutting or planting season, the beds are more accessible than the level ground; but having had the command of the water last summer, by a mill or engine, I dug out the peat into turf, having first laid aside the upper spit; the turf being removed, I shall return this spit into the ditch, and plant upon it; thus no ground will be lost.

In the year 1796 I made an experiment on an acre of land of this quality. I ploughed one half of it, and the other half was dug with the spade, about fourteen inches deep; the sod of that thickness was inverted by the spade. The plantation on the

ploughed land was very weak, and failed in many places; that which followed the spade did better; but they are both so bad, that they must be renewed this year. On the former, the best land lay uppermost, which, when deprived by the heat, of its moisture, derived no assistance to support the plants from the peat that lay underneath; on the latter, some of the best land was laid in the ground, but not deep enough to retain a sufficient quantity of moisture. The preceding year I planted in a piece contiguous, on banks as before described; and there the osiers do well.

I have a rich loam lying on a bed of potter's clay. The situation is low, and exposed to the water. French osiers were very scarce, and I could procure only a few hundreds last year; determined to eke them out as far as I could, I laid them down in their whole length, and pegged them on the ground; they struck good roots into the earth, and threw out abundant shoots.

This experiment, together with that of planting upon banks, will enable us to answer the question often asked, "Of what length ought the set to be?" It depends entirely upon the nature and situation of the land. There should be so much of it in the ground as to enable it to procure moisture; and so much of it out of the ground as to make it accessible in the cutting season, where much weeding is not required; and where there are no floods, or where they subside quickly, there ought to be very little of it out of the ground. The nourishment, in that case, will pass immediately from the roots to the rods, or shoots, without the burden of first, supplying the head or stock.

Every experiment that I have made confirms my opinion, that the autumn, and not the spring, is the most proper season for planting. Those who think with me say, that the fall of the leaf indicates the proper time to cut the sets; it certainly is so in general; but the leaf of the osier, like that of the oak and other trees, will sometimes prolong its departure. The stagnation of the juices is the true criterion by which to judge: not on account of the set, but of the trunk, lest, if you amputate it whilst the juices are in circulation, it should bleed to death. I have planted in the first week of October, and the sets appeared to remain torpid for the remainder of the year; about Christmas I took up several of them, and was much pleased to find they had struck root, although they had given no outward appearance of vegetation from the time of planting. It is probable that the earth retains a sufficient portion of the summer heat until the autumn, to give life to plants at the root, when the atmosphere at that time may be so cold, as to discourage any exertions above ground; and perhaps nature may be more vigorous when her operations are confined to one point.

When you plant in spring, the set seems (if I may speak so figuratively) to have its attention distracted by two operations not very homogenous, the one upwards, the other downwards. It is impelled to shoot its radicles into the earth, to form its stability, and procure sustenance; and it is called upon at the same time to put forth its leaves and branches. To speak without a figure, the prolific sun and air conduce to exhaust the juices, in extending the shoots before the roots are sufficiently strong and large to support the drainage; hence it is that, contrary to the commonly received opinion, a warm and dry spring is always injurious to the young plantations. If there be not sufficient rain to convey sustenance by the leaf and bark, in aid of the small quantity procured by the root, the plant must die or dwindle, and it is very observable that the first vigour of the late planted set is a sure prognosticator of its decline or dissolution. In the autumn of 1795, I made a small plantation, and on the remainder of the piece I planted in March following. In the beginning of May, those last planted were the forwardest, which, for a time, staggered my opinion of the most proper time for planting; but in June, those planted in the autumn had much the advantage, and have continued to grow well. Those that were set in the spring, decayed in summer, and many of them died. When the fibres have been formed before the winter, or when a tendency to form them has been observed, by the swelling of the bark, and particularly at the eye, the plant is enabled to charge itself with a sufficient portion of the juices to answer the demand of spring.

The rule, therefore, which I lay down for myself, where no obstructions are raised by the water, is to plant as early in the autumn as I can cut the sets, without endangering the parent stock."

Notwithstanding the prevailing notion, that osiers will not thrive in any situations but such as are wet, we have the testimony of a considerable planter to the contrary. This person has some of the most healthy and flourishing plats we have ever seen, in situations high and dry; and we are informed by him that the basket-makers prefer, for the generality of work, osiers growing in these situations, to those produced in low and marshy ground.

His ground was well manured and sown with turnips, and the sets or cuttings (which were eighteen inches in length) put about ten inches into the ground, and about one foot nine inches asunder. This person differs from Mr. Phillips, and prefers spring planting, which we believe to be the prevailing custom in the western counties, where the following sorts are mostly planted; namely, the brown-red, orange-red, and yellow. But as the basket-maker has occasion for various qualities of osiers, and each of these kinds has its peculiar advantages, the planter should put in some of each sort; as this will enable him in a short time to ascertain what kind suits best with the soil and situation.

In the trial of another cultivator, detailed in the *Transactions of the Society of Arts*,—" the soil is a strong clay, resting on a retentive clay subsoil of great

great depth. It has long been in a state of tillage, and is inclosed by flourishing woody hedges. The soil is naturally of a weak nature, has been much impoverished by bad management, and, as arable land, is not worth five shillings per acre. The greater part of the plantation in the year 1800, consisted of oats, and received only one ploughing of a mean depth, previous to planting. Nine acres were wheat in 1800, after the summer fallow. Three acres in the same field with the nine, were sown with grass seeds, in the autumn of 1800, and were planted at the same time with the rest, without any preparation whatever, except that of harrowing once in a place. Eight acres, which were last planted, were in various states of tillage; some were a good fallow in 1800; some were sown with grass seeds in the autumn of that year; and some were very grassy, and had lain all the summer without ploughing. The grassy part, and the part sown with grass seeds, were ploughed once before planting, but the part which was summer fallow, was not ploughed. The planting was began on the 9th of February, 1801, and continued till the whole was finished, which was on the 23d of March. The sets were large cuttings of about eighteen inches in length, thrust into the ground by hand, having from four to six inches of their length above the surface. They were all planted in rows, from twenty-two, to thirty inches asunder, and the sets from twelve to twenty-four inches asunder in the rows; but few were planted at the widest distances."

He adds, that "the plants made a more vigorous shoot in spring, then they did afterwards; but they are allowed by judges to look uncommonly well. Very few sets have failed, perhaps not above an hundred on an acre, except in the field last planted, where the dead sets are more numerous. This may be owing more to the treatment the sets received, than to the time in which they were planted. They were brought round the North, and South Forelands, were put out of the ship into a barge, and from thence into a waggon, and then remained some time before they were planted. Those plants that succeeded, wheat are much the best osiers; and those planted on the seeds without ploughing are the worst. They are invariably the best where the ground is cleanest; and from this circumstance he is led to think, that summer fallowing before planting would be judicious management. A neighbour of his, he says, planted 350 sets in his garden, 341 of which produced osiers; the rest died. The soil of the garden is clay. They were planted the latter end of March, in rows, thirty inches by twenty-one inches asunder, with beans between the rows. The 341 sets have produced a bundle of osiers of about thirty-eight inches in circumference; and some of them are upwards of ten feet in length. This he thinks proves, that the soil is congenial, and the tillage favourable to the growth of osiers. In the plantation already mentioned, there are several sorts, bnt principally those known by the name of the *new kind*." This experiment was made by Mr. Cherry, at New-wood farm, Stoke D'Auberton, in Surrey.

The following method is practised, as stated in the fifth volume of the Farmer's Magazine, in the fens, many holts (as they are provincially called,) or plantations of osiers are raised, which beautify the country, keep the stock warm in the winter, and provide much useful wood for baskets, cradles, and all kinds of wicker work, and also for cribs for cattle to eat straw or hay out of, and to make stows or hurdles to fence in stacks, part land, &c. &c. or they make hedges that will last four years well, and if allowed to grow five years, many of them would make fork shafts for hay or corn.

These holts or plantations of osiers are commonly made in the middle of the land, in the north and east corners, and sometimes at any end, side, or place, that appears most easy, or in any respect, the most desirable.

The situation and size of these holts vary exceedingly. Sometimes they are made in the middle of lands, from 10 to 60 yards square, and in others, in the sides or ends, of from 1 yard wide to 11, and from 10 to 100 yards long.

The mode of planting is very simple; it is, first to dig the land from 6 to 12 inches deep, and then to prick down cuttings of 4 years growth, and 18 inches long, at about three feet distance from each other. The soil should be moor or clay, or any that is low and wet; if drowned half the year, it will be but little the worse.

These holts or osier plantations must be fenced round, either with dikes which is most common, or with hedges which is most convenient. The proper season for making them (they seldom fail of growing at any time) is from the fall of the leaf till very late in the spring, and the sets are very cheap. Such plantations are cut annually for baskets, skeps, scuttles, cradles, and all kinds of wicker work, but when the osiers are kept for sets, or to make hedging wood, or for stows or hurdles, they are cut only once in four years. Wherever the farmer has lands that are suited to this sort of cultivation, as there is a constant demand for such articles, he should never neglect making plantations, as nothing that he can put upon such land will pay him so well.

It is observed by Mr. A. Young, that the late Mr. Forby, of Norfolk, knew the value of these plantations well, for various purposes. Osiers planted in small spots, and along some of his hedges, supplied him with hurdle-stuff enough to make many dozens every year, so that he supplied himself entirely with that article, as well as with a profusion of all sorts of baskets, especially one kind that he used for moving cabbage plants, for which purpose they were much better than tumbling the plants loose in a

cart,

cart. The common osiers he cut for this purpose at three years, and that with yellow bark at four.

As the planting of osiers is considered very profitable to those who may have ground well adapted to it, we subjoin the following account of the expenses. Of one acre and a half of osiers, having fourscore boults (of forty-two inches girt) to the acre.

Weeding twice or weeding and hoeing,	£1	10	0
Cutting 2s. 6d. per score		15	0
Sorting 2s. 6d. per score		15	0
Whiting or stripping per load, all expenses	2	2	0
Binding per load		7	0

A load consists of sixscore boults of green or fourscore boults of white.

The business of a basket maker requires but a small capital either of money or ingenuity, in consequence of which it has been fixed upon as one of the most proper occupations for that class of our suffering fellow creatures, the indigent blind, for whom an Asylum was first opened in Liverpool in the year 1790, under the auspices of the Revd. Henry Dannet, Minister of St. Johns. The following account of the institution, selected from Aikin's History of Manchester, cannot fail of being interesting to all our readers. "In reflecting on the situation of those persons who labour under that heavy calamity the loss of sight, it must occur to every one that this misfortune is aggravated by the want of employment for the mind, and by a consciousness of being useless to themselves, and in many cases a burthen to others. Frequent experience has, however, shewn, that blind persons are capable of becoming expert in various mechanical employments, and in some cases of making a surprizing proficiency in useful accomplishments. The education of persons in this situation requires, however, a different process from that which is usually adopted; and it was therefore suggested that if a school of industry were established for the blind, with proper instructors, the most beneficial effects might be derived from it. A subscription for this purpose was accordingly opened, and two houses fronting the area before the infermary, were rented, as a temporary accomodation for the pupils. The earnestness with which the benefits held forth by this institution, were grasped at by the unfortunate objects of its kindness, is a convincing proof that their inactivity was not voluntary, nor their situation hopeless. Several pupils were immediately admitted of different ages, most of whom applied themselves diligently to the particular employment to which their talents, or their fancy directed them. The principal occupations, which after a trial of some years, are found most suitable for the blind, independent of the use of musical instruments, are the making of baskets and hampers of various kinds, of white and tarred bears or door mats, foot-cloths, lobby-cloths, the weaving of sheeting, hag-abag, window sash, and curtain line, and the manufacture of riding-whips, the latter of which they execute with peculiar neatness. Besides affording the pupils instruction gratis, the Asylum allows them a weekly sum proportioned to the nature of their work, and the proficiency made by them, which with a small addition, in some instances, from their friends, or parishes, enables them to provide for their own support: thereby relieving them in a great degree from the painful idea of absolute dependence on the bounty of others; and which is scarcely of less importance, affording them an active employment for those hours, which would otherwise be spent in despondency and gloom. " We are happy in having it in our power of stating, that a great many institutions of a similar kind, have been set on foot in different large towns throughout the kingdom.

Baskets have, of late years, been introduced by coach makers, to form the bodies of gigs, for which purpose they are particularly well calculated, as we know of no other means whereby so much strength can be obtained with so little weight. The mail carts in London are baskets, and many of the stage coaches have baskets placed behind them for the purpose of carrying parcels; and we are convinced that the principle of basket-making might be extended, with good effect, to many other purposes, where the three qualities of strength, lightness, and elasticity, are required.

BLOCK-MAKING.

The art of Block-making was, formerly, executed entirely by hand with no other mechanical aid, than could be obtained by the use of a common turning lathe; but within these few years, the navy has been supplied with blocks made in the Dock-Yard at Portsmouth, by a set of machines erected there by the ingenious Mr. Brunel, which is conceived to be the most complete piece of mechanism in England, or perhaps in the world.

By means of this machine, the whole process, from the tree to the finished block, is performed with no other assistance than can be given by the most untaught labourer, as the only aid required is to convey the work, in its various stages, from one part of the machinery to another.

It would be useless to give a particular description of the various parts of this complicated machine under this head, as the exclusive right of using it is secured by letters patent to the inventor. Another reason is the great expence attending the erection of it, which would scarcely answer for any private concern. We shall, however, give a description of it under the article MACHINES, in the second part of this work, as various parts of the contrivance are applicable to many other purposes. The block used on shipboard consists of the shell, usually made of elm or ash; the pulley or sheave, made either of lignumvitæ or cast metal; the pin or axis of the pulley; and the strap, which is sometimes made of rope and sometimes of iron.

The different kinds of blocks are very numerous, depending on their size, use, form, number of pullies, &c. the bare enumeration of which would take considerable room. They may, however, be generally reduced to the following kinds: single, double, triple, and fourfold blocks, according to the number of sheaves they contain, which, for some particular purposes, extend to eight.

We shall now endeavour to give some idea of the manner of manufacturing blocks, as it is commonly practised, describing each part under its particular head, and beginning with the shell.

Having sawn out the wood to its proper width, length, and thickness, the corners are taken away; after which, if it is for a single block, the workman gauges the mortise hole, which is to receive the sheave in the middle of the block, allowing it one-sixteenth wider than the thickness of the sheave, and once the thickness longer than the diameter of the sheave. But, where more than one sheave is placed in the same shell, partitions between each sheave are necessary, otherwise the rope would be subject to slip out of the groove in the edge of the sheave, and the pin, from the width between the two cheeks, would be very apt to bend; these partitions are allowed one-sixth less than the sheave hole. The block thus gauged, is fixed firmly to the bench or cleave, in which situation it is held by wedges, and a hole being bored at each end of the sheave hole, half the way through its thickness, it is reversed, and being fixed again, the holes are met by boring from this side; the remainder of the wood is then removed by a mortise chisel with a bar, similar to those made use of by wheelwrights for mortising the knaves of wheels.

If the block is intended to have an iron strap, it should be applied before the mortise or sheave hole is cut out of the middle of the block; but this is not the case where rope is made use of, that being applied by the rigger after the blocks are on board the ship. Straps of this kind are usually fitted with an iron eye or thimble, and sometimes with a hook, according to the purposes for which they are designed. There remains now only to make the hole for the reception of the pin; it must be about one-tenth smaller than the diameter of the pin for which it is intended, in order to make it drive tight; this hole is made square on one side, and the pin is left square at one end for the purpose of preventing it from turning round in the hole.

The edges and corners of the shell are next rounded, first with the stock shave, which removes the larger parts, and then with the spoke shave, to finish and smooth them.

Blocks that are intended for the merchant service, differ from those used in the royal navy; the former being rounded off, leaving a small square on the edges, and the latter are left thicker upon the edges of the cheeks.

The next operation is the scoring, or grooving, for the reception of the strap; for which purpose the blocks are gauged, and being fixed as before, the groove is cut so deep at the ends as half the thickness of the strap, and gradually tapering to nothing at the pin. The same rule holds good for double strap blocks, first gauging it on both sides of the pin for that purpose.

After the score is cut, the sheaves are fitted; they are one-tenth thicker than the diameter of the rope intended to run on them, and five times that thickness in diameter. The hole for the pin is made through the centre of the sheave by a bit, fitted to the turning lathe, or with a stock and bit, and opened out with an auger, one-sixteenth larger than the pin, to enable the sheave to turn freely.

Coaked sheaves are such as have brass centres, or

coakes

coakes, let in on each side the sheave, made of cast bell metal, of a triangular form; the corners of both the coakes are kept opposite each other, so as to admit of three rivets passing through them, for the purpose of confining them together. When this is done, and the hole made, the sheaves are fitted to the turning lathe, where they are faced, and the groove turned on the edge for the rope to run on.

The pins are also fitted in the lathe, and turned smooth and cylindrical, except the head, which is left square for the purpose before stated.

After the sheaves are fitted, the inside of the sheave hole, at one end of the block, is gauged hollow, to admit the rope, and correspond with the sheaves; and a small neat chamfer is taken off the edges.

For the strapping of Blocks, the following rules will be found serviceable. A seventeen-inch block has a five-inch rope strap, and every inch in length above or under, to a twelve-inch block, has half-an-inch, more or less, sized rope allowed for the strap; an eleven-inch block has a three-inch strap, a ten and a nine-inch block two-inches and half; an eight and a seven-inch block, two inches; a six-inch block one and half inch; a five and a four-inch block one inch.

When blocks are bound with iron, the score is sunk sufficiently deep to admit of the whole thickness of the strap, except at the pin. Iron straps vary in thickness, from one inch to a quarter of an inch, allowing for their breadth three times their thickness, or thereabouts; of course it is ever to be taken into the account, that if the blocks are intended to bear any extraordinary strain, it will be necessary to give the straps more strength than the above proportions admit of, more particularly as this extraordinary strength is required, most commonly, in parts of the ship where the weight of the block is of less importance. The case is, however, very different for such blocks as are intended to be used aloft, where weight is ever to be avoided; it should, therefore, be the object of the workman to give as much strength as possible, with little weight; and this is best done, by using the choicest materials for work of this kind. The cat-block must have a strong strap and large iron hook, which hooks the ring of the anchor in catting. The top-block should have a stout iron binding, with a strong short hook. Top tackle blocks have strong iron bindings, the upper block with a tackle-hook, and the lower block with a swivel-hook. The swivel, in iron bound blocks, serves to turn it occasionally, in order to untwist the parts of the rope which form the tackle, otherwise a considerable loss of power would be the consequence.

In rigging, the whole length of all the different sizes of block-strapping, is got upon the stretch, and hove out tight, for worming and serving; it is then wormed and served, and cut into shorter lengths, suited to the different blocks.

The strapping of jur-blocks is wormed, parcelled, and served; strapping of four inches diameter, and above, is wormed and served, and all under four inches are only served with spun-yarn; except the sprit-sail brace, bunt-line, and leech-line blocks, that are lashed under the tops; these are served with spun-yarn over the splice, and the tail left half a fathom in length. Jur-blocks are double scored, and the double and triple blocks are strapped with a double strap, thus: the block is spliced together at the ends, and, when doubled, to be the size of the block and circumference of the yard; it is then doubled, and the block seized in the bight, with a long and short leg; the splice laying in the arse of the block.

Before the strap is applied, the pin and sheave should be examined, and the score should be well tarred. The block is set well into the strap with wedges, in the following manner: the four parts are frapped together with rope-yarn under the block, with a chock between; and the wedges are set between the breast of the block and the chock. Then the strap is nippered with a heaver round the block; the wedges, chock, and frapping, taken away, and the block hung upon the stake-head, or post, and the strap well seized together, close under the block, with nine under, and eight riding-turns, every turn strained tight round with a heaver, and crossed each way two turns.

Jur-blocks of the mast-heads, are strapped with long eyes, to receive many turns of the lashing; and the block is seized into the strap, as before, as are all the seizing blocks according to their sizes.

A TABLE OF THE DIMENSIONS OF STRAPS FOR LASHING AND SEIZING BLOCKS.

Size of the Blocks.	Circum. of the Straps.	Length of the Straps.	
Inches.	Inches.	Feet.	Inches.
17	5	7	4
16	4½	6	8
15	4	6	0
14	3½	5	4
13	3½	4	11
12	3½	4	6
11	3	4	2
10	3	3	9
9	2½	3	4
8	2½	3	0
7	2½	2	9
6	2	2	6
5	1½	1	9
4	½	1	6

Blocks, strapped with eyes or thimbles, spliced in the ends, are seized tight into the bight, and the legs

legs left long enough to lash through the eyes, round a mast, yard, &c. as the top-sail clue-lines, clue-garnets, and sprit-sail clue-lines, &c.

Blocks strapped with a thimble, or hook and thimble, have the straps spliced together at the ends. The block is fixed in one bight, for the splice to lay on the arse of the block, and the thimble in the other bight: the seizing is put on between the block and thimble, with eight under and six riding turns, according to the size of the block, each turn strained tight by a heaver; the turns double crossed, and the ends stopped with a wall knot crowned.

Blocks strapped with double tails are fixed in the strap similar to blocks with eye-straps; and those with a single tail are spliced in and served with spun-yarn over the splice. Girt-line blocks are strapped in the house, and the girt-lines reeved, *See Elements and Practice of Rigging. Vol.* 1.

Bee-blocks are made of elm, in length seven-ninths, the length of the bee in depth, two inches for every foot of length, and in thickness seven-eighths of the depth. A block of this kind is trimmed square, chamfered on the outside edges, and fitted with a sheave in one end, and in the other end is cut a hole, to be fitted with a sheave, in case the other should fail. The sheave-hole is two-sevenths of the length of the block, and one-fourth the length of the sheave-hole, in breadth, and half the length of the sheave-hole within the end.

Bee-blocks are bolted to the outer ends of bowsprits, under the bees, and the bolts serve like the axis or pin for the sheaves to work upon; the fore-top-mast stay, reeves through the sheave-hole at the foremost end of the starboard bee-block, and the fore-top-mast preventer, or spring-stay, through the sheave-hole, at the after end of the larboard bee-block.

Thick and thin, or quarter-block, is a double block with one sheave thicker than the other, and is used to lead down the top-sail-sheets, and clue-lines.—Although these are used for the top-sail-sheets, and intended for the clue-lines, a single block would be cheaper and better, as the thin sheave is seldom used for the clue-lines, it being found rather to impede than to facilitate. Small ships in the merchant service, have a double block lashed in the middle of the yard, as the quarter block, through which the sheets reeve, and lead down on opposite sides. Large ships in the merchant service, have a single block lashed on each side of the middle of the yard, and the sheets reeve on their respective sides, and lead down by the mast.

Brail-blocks, in rigging the mizen yard, are strapt together in one strap, and lie over the yard, and seize together underneath; the throat-blocks next the cleats to the mast: the middle-blocks in the middle between the throat-block and peek; the peek-blocks about three or four feet within the cleats at the peek.

Voyal, or viol-block, is a single sheaved block. The length is ten times the thickness of the sheave-hole, which is three-eighths more than the thickness of the sheave; the thickness of the sheave is one-tenth more than the diameter of the viol; and the diameter of the sheave is seven times the thickness. The breadth of the block should be eight times the thickness of the sheave, and the thickness two-sevenths of the length. This block is double scored, the sheave is coaked with brass, and the pin is iron, and nearly as thick as the sheave. It is used in heaving up the anchor. The viol passes round the jeer capstan, and through the block, which is lashed to the main-mast, and the cable is fastened in a temporary manner to the viol in several places. It is seldom used except in the largest ships in the royal navy.

Cheek blocks, or half-blocks, are made of elm plank; the length being twice and a half the depth of the top-mast head; the breadth is seven-eighths of the depth of the top-mast-head, and the thickness half that depth. The depth of each tenon, and thickness of the cheek, when the sheave-hole is cut, is each three eighths of the whole thickness, so that the remaining two-eighths are the sheave-hole. The three tenons each are two inches square, one in the middle, and one at each end; and the length of the holes is more than the breadth of the block, by the thickness of the sheave. The back of the block is divided into three parts, and one-third on each side is bearded down to one-third the thickness of the cheek on each edge. Pins of iron are made for fastening them to the top-mast head, and for durability, the sheave-holes are coppered. Cheek-blocks are bolted to the thwart-ship sides of the top-mast heads, close up under the cap, the bolts serve as the pin, or axis, for the sheaves to work on; the jib-stay, and haliards, and foretopmast stays, sail-stay, and haliards reeve through the cheek blocks at the fore-topmast head, and the maintopmast stay-sail haliards, and middle-stay sail-stay and halyards reeve through the cheek blocks, at the main-top-mast head.

Sister-blocks, are similar to two single blocks, and are formed out of a solid piece, about twenty inches long, one above the other. Between the blocks is a scoring for a middle seizing; a round head is turned at each end, and hollowed underneath to contain the end seizings; along the sides, through which the pins are driven, is a groove or scoring, large enough to receive part of the topmast shrouds, in which it is seized. These blocks receive the lifts and reef tackle pendants of the top-sail-yards.

Clue line-blocks, in rigging the sprit-sail-yard, are strapped with two eyes, and are lashed through those eyes round the yard, three feet without the slings: the lashing to be upon the yard. In rigging the sprit-sail top-sail-yard, these blocks are strapped with two eyes, and are lashed through those eyes round

round the yard, about two feet without the slings. The clue-line blocks, in rigging the top-sail yards, are strapt with two lashing eyes, and lash upon the yard three feet without the slings; the blocks hanging underneath the yard, through which the clue-line reeves, and is strapt with a knot, and leads down upon the deck. In rigging the top-gallant yards, the blocks are strapt with two lashing eyes, and lash upon the yard three feet without the slings. The blocks hang under the yard, through which is reeved the clue-line, which is stopt with a knot. The leading part leads down the mast, and into the lower shrouds. Some sloops and light rigged vessels have no clue-line blocks; they lower the yards.

Mr. Brunel has made a great improvement in these blocks. The old clue-line, or clue garnet-block, (for they are the same except in size) was a single sheaved block, strapped with two eyes; a knot was made in the end of the clue-line or garnet, just at the place where it was attached to the clue of the sail, to prevent the corner thereof being drawn into the block. This was not effective, and frequent inconvenience arose, for the sail being constantly in motion, the rope had a great tendency to get entangled with the sail, and drawn over the sheave. To prevent this, the sheave is situated in the centre of the block, so as to be wholly inclosed except a mortise, where the sheave is put in. The strap surrounds the lower part of the block, then both ends pass through a hole in the upper part, crossing each other. They are then formed into an eye, by which the block is suspended from the yard. By this means no accident can happen, as the garnet rope is so inclosed in the block.

Strap bound blocks, are single blocks, with a shoulder left on each side, at the upper part, to admit the strap through a little above the pin. These blocks are used at the clues of the square-sails for the clue-garnets, or clue-lines; and under the yards, the shoulder prevents the strap from chafing.

Nine-pin blocks, are used to lead the running ropes in an horizontal direction. The shells, made of ash, or elm, resemble the form of a nine pin, though flattened on the sides. Their lengths are generally confined to the places in which they are fixed, and this is for the most part under the cross pieces of the fore-castle and quarter-deck bitts. The breadth of the block, sheave, &c. is governed by the rope, and taper at the ends to three eighths of the breadth of the middle; the pins at each end serving as a vertical axis, is two-thirds of the size of the end. The thickness is five-eighths of the breadth. These blocks may be turned in a lathe, and flattened afterwards with a spoke-shave.

Shoulder-block, is a large single block, left nearly square at the upper end of the block, and cut sloping in the direction of the sheave. Shoulder-blocks are used on the lower yard arms, to lead in the top-sail-sheets; and on top-sail yards, to lead in the top-gallant sheets, and by means of the shoulder are kept upright, and prevent the sheets from jambing between the block and the yard; they are also used at the outer end of the bomkins, to lead in the fore tackle.

Rack blocks, are a range of small single blocks, made from one solid, by the same proportions as single blocks, which ends in form of a dove's tail for the lashing, by which they are fastened athwart the bowsprit, to lead in the running ropes; they are seldom used.

Long tackle blocks, are two single sheaves placed one above the other in the same shell. The lower sheave is only two-thirds the size of the other; it is used in combination with a common single block, to form the long tackle, for loading, or any other purchase. In the navy and East India service they are used as yard tackles. The rope is reeved through it in the same manner as it would be through a common double block; but it is preferred where it is convenient, because the strap being in the center of the resistance, it hangs more steadily than when the sheaves are on one pin.

Monkey blocks, are sometimes used on the lower yards of small merchant ships, to lead (into the mast, or down upon the deck) the running rigging belonging to the sails. The shells are made of ash or elm. Some are only small single blocks attached by a strap and iron swivel to iron straps, which embrace and nail to the yard the block turning to lead the small ropes in any direction; others are nearly eight square, with a roller working in the middle, and a wooden saddle beneath to fit and nail to the yard.

Shoe blocks, are two single blocks, cut in a solid piece, transversely to each other; they serve for legs and falls of the bunt-lines, but are seldom used.

D blocks are lumps of oak in the form of the letter D, from 12 to 16 inches long, and 8 or 10 feet wide; they are bolted to the ship's side in the channels to receive the lifts.

Main sheet block is used for the sheet tackle of the main-sail-booms of small vessels. The pin projects from each side of the block, being in all the same length as the block; the fall or rope of the tackle is belayed or twisted round this pin, to stop it. This block is either single or double, and has a hole through the end to receive its strap.

Snatch block, is a single sheave, with a notch cut through one of its cheeks, to admit the rope or fall to be lifted in and out of the block, without putting its end through first. It is a convenient block for heaving any rope in the navy. The snatch blocks are iron bound, terminating at the notched end of the block, with a swivel hook or an eye-bolt, large enough to receive several turns of lashing, which fastens the block to its fixed support. That part of the strap over the notch in the side lifts up with a hinge, and is confined down, when the rope is in the block, by a small pin put across through the end of the

the pin of the sheave, which projects up the block, sufficiently to pass through an eye made in the hinge part of the strap. The strap on the other part of the block is let into the block, and confined by the pin and some nails. These blocks are used for heavy purchases, where a warp or hawser is brought to the capstan.

Clue-garnet blocks.—These are single sheaves suspended from the yards, by a strap with two eyes; a lashing surrounds the yard and passes through the eyes, so as to suspend the block beneath the yard; these blocks receive the clue-garnets or ropes which haul up the clues of the sail; this is applied to the main and fore-yard.

Deep sealine block, is a small wooden snatch-block, from about nine to ten inches long.

The blocks lashed to a ships principal yards, are as follow.

To the lower yards.—The jeer-block; buntline-blocks; leech-line-blocks; lift-blocks, and topsail-sheet blocks, strapped together; quarter and slab-line-blocks, strapped together; clue-garnet blocks; tricing-blocks; preventer brace blocks; pendant blocks; studding-sail halyards blocks.

To the topsail-yards.—Buntline and tye-blocks strapped together; top-gallant-sheet block, and lift block strapped together; jewel block and brace pendant blocks; clue-line blocks, and block to lead down the top-gallant sheets.

To the top-gallant yards.—Jewel, clue-line, and brace pendant blocks.

To the mizen yard.—Jeer-block; derrick-block; signal halyard block; throat brail, middle brail, and cook brail-blocks.

To the cross jack-yard.—Quarter-blocks; jeer blocks; and lift and topsail-sheet blocks strapped together.

To the bowsprit.—The bee block, bolted to the bowsprit at the outer end under the bees; fore bowline-blocks, lashed on each side the fore-stay collar; fore-topsail-bowline-block lashed to an eye bolt in the bowsprit cap.

Fish-block, is hung in a notch at the end of the davit, and serves to haul up the flukes of the anchor to the ships bow.

Girt-line blocks, in rigging the fore mast and main and mizen masts, are lashed round the mast head, above the top of the cap; one to hang on each side. The girt lines that reeve through them, lead down upon deck for hoisting the rigging, tops, and cross-tree, and the persons employed to place the riggiug over the mast head.

Cat-block, is employed to draw the anchor up at the cat-head.

Bunt-line blocks, are lashed in rigging the lower-yards, like the leech-line blocks in the middle between them and the slings of the yard. These, in rigging the topsail yards, are spliced round the strap of the topsail tye-block upon the yard.

Derrick-block, in rigging the mizen yard, is strapped with eyes, that go round the yard, and lash underneath, between the slings and the outer yard-arm or peek; the other block is cross seized into the strap, has an eye spliced in each end, and lies upon the mizen cap, and seizes or hangs through the eyes under the cap, or upon the upper side of it.

Leech-line-blocks, in rigging the lower yards, are lashed round the yard, and through the eye of the strap, ten feet within the cleats on each yard-arm; the blocks hang on the fore part of the yard.

Lift-blocks, in rigging the lower yards, are spliced unto the top of the topsail sheet blocks; the lifts reeve through the block in the span round the mast-head, between that and the top-mast, then lead down abreast the shrouds, and reeve through a block fastened to the side, and are there belayed. In rigging the-topsail yards, the lift blocks are strapped with an eye to the side of the yard arm. The lift reeves through the lower sheave in the sister-block in the topmast-shrouds, and through the block on the yard-arm. The standing part hooks to a becket round the topmast-cap, and the leading part leads down the side of the mast, and belays to the dead eyes in the lower shrouds.

Made blocks, have the shell formed of several pieces of elm plank, suited to the thickness of the cheeks, sheave holes, and middle parts, and are strongly bolted together with three bolts at each end, driven through and clenched on a ring at the points. These blocks have flatter cheeks and more square edges, than other treble and four-fold blocks. Of this sort are large treble and four-fold blocks, for heaving down ships, or other heavy purchases. Smaller made blocks of modern invention, are formed of two pieces, joining in the middle; the pin working as patent rollers, let into the inside of the cheeks, which are bolted or rivetted together at the ends. These blocks are thought too complex for the Royal Navy, and are not so easily remedied in case of failure.

Slab-line blocks, in rigging the lower yards, are strapt with a short lashing eye, that seizes to the span of the quarter-blocks underneath the yard.

Top-gallant-sheet blocks, in rigging top-sail yards, are strapt with two lashing eyes, and lashed upon the yard, close within the clue-line blocks on each side.

Top-sail-sheet blocks, in rigging the lower yards, are put over the yard-arms, strapped with an eye of the size of the yard-arm.

Tricing-blocks, for the yard-tackles, are strapped with a short lashing eye, that seizes round the yard about one third of the length within the arm cleats; the blocks hanging under the yard.

Tye-blocks, in rigging the top-sail-yards, lashed at the top-mast-head close up to the rigging, under the collar of the stay, as the lower ones; and the blocks on the yards lash under the fore-part of the yard, as the lower ones, and reeve with a double tye, in large ships, and with a single tye, like the lower, in small

ones. The standing parts of the double tyes clinch round the mast-head, then reeve through the double block upon the yard, and up again, and reeve through the block on each side of the mast-head. The blocks are then spliced in their lower ends, and connected by their haliards to a single block, that is strapt with a long strap, with a hook and thimble, that hooks to a swivel eye-bolt in the channel on each side; the leading part comes in through a block lashed on each side; the foremost ones abaft the forecastle, and the after ones on the quarter deck.

Warping block is made of elm or ash board, shaped like the body of a bellows; the sides or cheeks are 8½ inches broad, in the middle, and tapered to two inches broad at the ends; the back or longest cheek, is sixteen inches long, and 7-eighths of an inch thick, with a hole bored through the upper end to receive a leathern strap; the upper cheek is 12 inches long, and 7-eighths of an inch thick, except the lower end, which is 1, 7-eighths inch thick, and forms the sheave-hole. The sheave is 1, 1-fourth inch thick, and 7, 1-half inches in diameter, made of lignumvitæ, coaked with brass; it is let into the cheeks one eighth of an inch, to prevent the yarn from getting between the sheave and the cheeks. The cheeks are fastened together at the lower end with three screws and nuts: and the pin, which is iron, is seven inches long, driven through the middle of the block, with a shoulder on the upper side, and clinched at the point on the lower side of the shell; the upper part of the pin is tapered small, and a wooden handle rivetted upon it. The cheeks have a broad chamfer round the outer edges; the inside edges, and inside of the block above the sheave, are lined with thin iron neatly screwed on, to prevent the block from wearing. This block is finished in a neater manner than blocks in general, and is seldom used but by rope-makers, to warp off the yarn into hauls, for tarring.

BOOK-BINDING.

The art of Bookbinding, there can be little doubt, must be as ancient as that of writing books; for, whatever might be the substance on which the work was written, some mode or other of uniting the parts became necessary. The earliest method that we are acquainted with, is that of rolling the different parts or sheets round cylinders. Phillatius, a learned Athenian, was either the inventor or improver of this mode of binding, his countrymen having erected a statue to his memory on that account. This method consisted of first glueing together the leaves, and then attaching them to cylinders, round which they were rolled, this is called Egyptian binding.

The present manner of binding books is, however, of great antiqnity; some authors state it to be the invention of one of the Attali, kings of Pergamus, to whom we are also indebted for the mode of preparing parchment.

Modern, or square binding, is of two kinds: the one particularly adapted to printed books, where leather forms the general covering, and the other more immediately applied to account books, where parchment or vellum is made use of as the outside covering. We shall begin with the former, and for the purpose of rendering the subject as clear and intelligible as the nature of it will allow, we shall arrange it under different heads, beginning with a description of the tools.

1st, The *Standing Press*, which is a large press, with its screw perpendicular, and similar to those used by paper-makers; this is strongly fastened to the room in any convenient situation, its use being to press the books flat, in various stages of their progress.

2d, The *Cutting Press*. This is very different from the former, and consists of two cheeks, or beams, of about three feet in length, laying horizontally on a tub or frame; in the off cheek is cut two inside screws, and in the near cheek, exactly opposite, is bored two cylindrical holes, near the ends, through which two wooden screws pass, and enter the nuts or inside screws in the off cheek. These screws are about eighteen inches long, having large heads, through which are bored at right angles to each other, two holes, for the purpose of introducing the press pin, by which the books are pinched between the cheeks. Whatever, therefore, is to be put into this press, must not exceed in length the distance between the two screws. On the upper side of the off cheek, and running lengthwise, are nailed two slips, about an inch and half asunder, forming a groove or channel, in which the cutting plough is to run.

3rd. The *Plough*. This, like the former, consists

sists of two cheeks, made light and small, which are drawn together by a single screw. To one of its cheeks is affixed a knife, which lies flat upon the upper face of the cutting press. The mode of using it is this: having placed the book intended to be cut in the cutting press, with as much of its leaves as you intend cutting away, rising above it, place the plough in the groove, and open its cheek so much as to let the point of the knife pass without cutting any part of the book. Grasp with the right hand the head, and with the left hand the other end of the screw, and proceed to draw it towards, and push it from you, shuffling the screw a little each time it passes the book; and in this manner proceed until the knife has removed that part of the book which is intended to be cut away.

4th. The *Sewing Press*. The bed of the sewing press is commonly a piece of hard wood, about one inch thick, one foot wide, and about two feet long. A groove is cut through it, which extends near its whole length, and about one inch in, from one of its edges; this groove may be about three quarters of an inch wide. Into the bed is fixed two wooden screws furnished with nuts, on that side the board in which the groove is made, and as near the ends as is consistent with strength, and the centre of the screws agreeing with the centre of the groove; a piece of wood is then fitted on the screws, having two holes in its ends, of sufficient size to admit of its sliding freely up and down on the threads of the screws. The middle of this bar is turned round, leaving the ends flat, for the purpose of making the holes; and, as the bar rests upon the nuts, it rises or sinks with them. Its use is to stretch the cords or bands to which the sheets or sections of a book are sewn. To perform this, fasten one end of the cord to the bar, and the other end to a small key, first passing the cord down through the groove; proceed to fasten the number of bands required (which is six for folios, and five for quartos and smaller sizes) in the same manner, and bring the whole to a proper degree of tightness, by means of the two nuts, which force the bar up from the bed of the press.

5th. The *Beating Stone* is commonly fourteen or fifteen inches square on the upper surface, which is required to be smooth. The stone should be hard and sound, and of considerable thickness. It is generally placed in a barrel nearly filled with sand, which keeps it from springing.

6th. The *Beating Hammer*. A short heavy hammer, sometimes twelve or fourteen pounds, resembling in some measure the shoemakers' hammer, having a smooth and convex or round face, the handle being about six inches long. Its use is to beat the book until it becomes solid, flat, and smooth; to perform which, about one hundred pages are laid on the beating stone at a time, and held by the corner, firmly, between the finger and thumb of the left hand, to prevent the sheets shifting, whilst they are beat with the hammer in the right hand, taking care to change the book about, so as to beat the whole equally, and frequently changing the order of the sheets so as to present each sheet to the action of the hammer. When books are fresh printed great care must be taken not to beat them too hard, that the print from one page, may not set off on that which is opposite; and when there are prints, silver paper should be placed before them, to prevent the same thing happening; indeed, where the engravings are valuable, they should not be put into the book until it has been beaten.

7th. *Gold Knife*, commonly a long spatula, or painter's knife, which is used for cutting the gold leaf into proper sizes on the gold cushion.

8th. The *Gold Cushion*. This is made by laying a quire of blotting, or other soft paper, on a flat board of the same size, and covering it with a piece of rough calf skin. It should be kept carefully from grease, which is best done by rubbing some warm ashes over it before it is used.

9th. The *Backing Hammer*. For this purpose the common shoemaker's hammer is used, of the largest size.

10th. *Ivory* or *Bone Knife*, for folding or cutting paper.

11th. *Pressing Boards*, are flat boards made of well seasoned beech, the small ones being about 5-eighths of an inch thick, and the large ones one inch. The sizes depend on the books they are intended to press, and therefore, are known by the same name, as octavo boards, quarto boards, &c.

12th. *Cutting Boards*, are slips of feather edged board, thinner one side than the other, the thick side being from one half to one inch, which is reduced half on the thin side.

13th. *Backing Boards*. These are the same as the cutting boards, with this difference, that they are a little bevelled on the thick, or upper edge, in order to make the groove which they are intended to form, sharper.

TOOLS FOR FINISHING OR LAYING ON THE GOLD.

14th. *Rolls*. These are brass wheels of various thicknesses, having different figures and designs engraved, or rather embossed on their edges. They are mounted on a spill of iron, terminating on two cheeks, through which a hole is made to receive the pin on which the roll turns; the spill is driven into a long wooden handle, which, when used, rests against the shoulder; they are used for rolling the bands on the backs and sides of books.

15th. *Pallets* are pieces of brass of about two inches long, set in a handle, and engraved like the former. They are much less expensive, but do not make the same dispatch, and they are only applicable to the backs of books.

16th. *Back tools*, are buttons of brass, of various sizes, set in handles, and cut or embossed with various devices, such as flowers, stars, &c.

17th.

17th. *Alphabets* of different sizes, all of brass, for lettering the backs of books: they are distinguished by octavo, quarto, and folio alphabets, according to their size. The manner of using the finishing tools will be given when we treat of that part of the art.

Books are sent from the printer in quires; the sheets are then folded into a certain number of leaves, according to the form in which the book is to appear, viz.—two leaves for folio, four for quarto, eight for octavo, twelve for duodecimo, &c. This is done with the ivory knife or folder, and in the arrangement of the sheets, the workman is directed by the catchword and signature at the bottom of the pages. Great care should be taken in the folding of a book, as its beauty will be much injured by any inattention to this particular: for when cut, the margin will appear unequal, and in books with small margins, there is some danger of cutting the print. When the leaves are thus folded, they are next beaten, as before described, and the blank paper at beginning and end being added, each book is divided into small parcels, between each of which, a pressing board is to be placed, and the whole put into the standing press, where they should remain for some hours.

When the sewing press is prepared with bands or cords, according to the foregoing directions, the books are taken from the standing press, and placed upon the table or bench, with the title-page upwards. The bands are now to be adjusted, which is done by keeping them at an equal distance from each other, allowing the distance between that band next the head of the book, to be somewhat greater than the distance between themselves, and the distance of the band, which is next the tail or bottom of the book, to be greater than either. It should here be observed, that when the bands are meant to project, as is sometimes the case, they are suffered to lie on the surface of the back, but when the back is intended to be fair and smooth, grooves are cut in the back, by screwing the book in the cutting press, and making a saw-carf for the bands to lie in; in either case the mode of proceeding is as follows; lay the blank leaf section on the bed of the sewing press, with its head from you, and having put the left hand into the middle of the section, with which you must keep it against the cords, pass with the right hand the needle through the middle of the section, about one inch from the head, turn it round the first band and go to the second, and so on to the last, and finally, bring the needle out about one inch and half from the bottom. This fixes the first or blank leaf section. The second, or title sheet is proceeded with in the same way, only changing the direction of the work, this being from tail to head, and the former from head to tail; but as the back would be too much swollen with the thread, were each set or sheet sewn throughout (unless in cases where the section or sheets are thick,) it is necessary to sew on two or three sheets in once passing from head to tail, by taking one stitch in the first sheet laid down, and placing a bit of card in the middle of the sheet before the left hand is withdrawn, in order to find it again with readiness; then lay down a second sheet and make the second stitch in this, just as if the first had been continued, withdraw the hand from this, and place a card as before; then return to the first sheet and make the third stitch, and again return to the second sheet, and so on alternately till you reach the end, which is called the kettle stitch. The last two or three sheets should be sewn all through like the first, as the beginning and end of a book serving for the hinge of the covers, require more strength. If three or more sheets are sewn on, the same method is pursued. A little paste should be rubbed along between the first and second sheet, to attach them more firmly together. Care should be taken not to draw too hard on the thread at the kettle-stitch, which would make the book thinner there than elsewhere.

Before the book is glued, stand the book on the table with its back uppermost, supporting it between the two hands and with the thumbs, open and adjust the sets, so as to make it equally thick on all parts; then knock the back even and flat by turning it downwards and striking it smartly on the table, while it is held firm between the hands. Hold the book in the left hand, with the back upwards, and with a brush glue the back even and well, with glue of a tolerable consistence. This should always be done near the fire in cold weather, as the glue is apt to be chilled, in which case it will not take sufficent hold on the paper. After the books are glued they must not be dried too hastily as that would render the glue too crisp. When the glue is sufficiently dry, paste the first and second leaves of the end or blank paper together, and with a blunt knife, after having untwisted the cords or bands, scrape them to a point; then, with the backing hammer, *round the back* by laying the book on its side with its back from you, hammering gently on the edge of the back, while the hand draws the upper part of the book towards you; then turn the book and repeat the same on the other side. By this means the back is rounded and prepared for backing, or in other words, for forming a groove or shoulder for the paste-board sides of the book to lie in; to accomplish which, having placed the upper or thick edge of a backing board about one eighth of an inch from the back, with the cords or bands free, turn the book and place another backing board on the other side in the same manner, holding the book firm between the fingers and thumb of the left hand, and taking great care that the boards do not slip, to prevent which, wet them a little with the tongue: in this position, with the book suspended between the fingers and thumb of the left hand, drop it between the cheeks of the cutting press, and screw it up with the right

right hand, letting it rise a very little above the surface of the press; examine whether the boards and back keep their position; then, with the press pin, screw the book up as tight as possible, and with the backing hammer beat the back round and even, causing it to spread as much as possible, and thereby forming the grooves for the reception of the boards.

The paste-boards being roughly cut with shears to something like the size, are cut to a proper width before they are put on the book, with the plough, to ascertain which, take the width of the book by placing one foot of the compasses close against the shoulder of the groove, and extend the other foot towards the fore-edge, piercing two or three leaves with it, in order to ascertain how much it is necessary to cut away; then allow as much more in width as you desire the boards should project beyond the book, mark it on them, and proceed to cut them with the plough. Place a paste-board on each side the book, and with the bodkin, scratch where the bands come, then lay the boards singly on a block and with the hammer and bodkin make two holes to each scratch, one about one quarter of an inch from the edge, and the other half an inch farther in. With a little paste between the finger and thumb rub the bands to a point, and pass them in through the first, and out through the second hole, and then draw them as close home as possible, cutting off the ends of the bands to about half an inch in length, rub the ends with a little more paste, and lay the board flat on the edge of the press, hammering smartly on the bands to close the holes on them and to make them flat and smooth.

The book being now in boards, with a fine point or knife, mark where the boards come on the side near the fore-edge. The next step is to cut the edges; beginning with the fore-edge, which is concave or hollow. This operation, though difficult to describe, is nevertheless very simple. To perform it, the back, which is now round, is made flat by introducing 2 pieces of thin iron 4 or 5 inches long near the head and tail of the book, between the paste-board and the back; the ends of the iron resting on the inside of the boards, and the back on the middle, the boards standing out from the book at right angles, forming a figure somewhat resembling the letter ⊥, the stem of the letter representing the leaves, and the arms, the boards. In this position the leaves are pressed between the flat of both hands, and the book struck upon the flat of the cutting press so as to take the round out of the back. Two cutting boards are now applied, one before and the other behind, bringing the front one, or runner, up so near to the mark, which was before described, as to leave the boards a sufficient square or projection beyond the leaves of the book; then raise the book, by pressing the boards between the fingers and thumb of the left hand, slipping out the irons as you raise it, but taking great care to keep the book from shifting. Then drop it between the cheeks of the press, which when done and the screws are pressed gently upon it, force it down till the runner, or front board, comes exactly even with the surface of the press, the back board rising as much above it as that part of the leaves of the book intended to be cut away, and proceed to cut it as before described. To cut the head and tail, the boards must be drawn as far down from the head, as the bands will admit. Then place the cutting boards as before, having previously marked on the paste boards, with a square, the quantity intended to be cut away; and cut through boards and all. To cut the tail of the book, draw the boards from the tail towards the head, and proceed as before. This is called *cutting in boards*. To cut out of boards, which is the way in which all school books are done, the fore-edges of as many as can be conveniently held in the hand, are cut before the backs are rounded, after which they are rounded, backed, and boarded, when they are again put into the standing press, and suffered to remain for some hours, and then taken out and the heads and tails cut as other books; but the paste-boards not having been cut to the proper width, previous to their being put on, are then cut, allowing a proper square, by means of a large pair of shears, like those used by tinmen. All kinds of account books are sewed on slips of parchment or vellum, and after being glued, the edges are cut, and coloured, and then the boards put to them by pasting the board to the first blank leaf, and the ends of the slips of parchment on which the book is sewn.

To return to the printed book; the edges must now be coloured, and having cut away a very small bit of the four corners of the paste-boards, next the back, it will be ready for *head-banding*, a name given to the small rope of coloured silk or worsted which is put at the head and tail of the back, the mode of doing which is, to roll paper under a board to the required size having, previously pasted it, and having taken a piece of it of a proper length for the book, (which must be fixed in the end of the press) with a needle and silk of one or two colours as is desired, pierce the back at one corner and bring it round the roll of paper, and having fixed the roll, twist the different colours of the silk alternately round the band or roll, crossing the one over the other as you change them, and fastening it occasionally as you proceed by repiercing the back with the needle. The back must now receive another coat of glue, and be lined with cartridge or other paper in order to render it smooth and to fix the head-bands. To cover it, you must wet the leather first, and having pressed the water well out, lay it on a paste-board, avoiding touching it with steel or iron, as that will turn it instantly black; and having cut it to the size required, pare the edges thin on a piece of marble or other smooth stone, with the common

shoe-makers paring knife, cutting from the rough or flesh side of the leather; when thus prepared, paste it evenly over with good paste, and laying the book on its side on it, bring the leather as tight over the sides as you can, turn the edges in, making the corners as neat and flat as possible, by cutting away all the leather which projects beyond the corner of the board, and doubling one over the other by stretching the leather a little, setting and putting the leather close as you proceed. After this lay the book again on its side, and rub the leather smooth with the edge of the ivory folder or paper knife, drawing the leather up over the head-bands, and setting it in, square and neat on them, and tye twine or thread round the book to nick in the leather by the ends of the head-bands. In drying it, set it with its back towards the fire on a clean board at some distance from it, (or, if in summer, in the sun) till the back is nearly dry, which is known by the leather assuming its primitive colour; as soon as this is perceived to be the case, with a folder, rub the back up and down, whilst warm, and the glue being softened by the water of the paste and the heat, attaches the leather strongly to the back; whilst the superfluous quantity, if any, is driven out at the head-bands, from which it must be removed with care, that they may not suffer injury from it.

Great care should be taken if books are dried by the fire, not to place them too near it, as the glue is very apt to show through the leather, and the books should frequently be examined, lest they should get too dry for setting. It should here be observed, that if the book is to be bound in rough calf, *i. e.* with the flesh side of the leather outward, it should not be wetted, but pasted on the grain side, and suffered to lie till sufficiently softened. The next stage is to marble, colour, or spot the sides and back, directions for which, and for colouring the edges, will be found at the end of this treatise, with the manner of preparing the colours. After the back is marbled or stained, it is ready for the lettering piece on the back. Take a piece of morocco, and proceed to strip or divide the grain from the flesh side, as follows; having cut through the grain or coloured side, in an oblique direction, with a knife, raise it with your nail so as to take hold of it, then by pulling the one from the other, it will render it thin and fit for your purpose. It is to be observed, however, that some parts of a skin of morocco are more difficult to separate than others, particularly near the neck; these parts will therefore be best reserved for other purposes, or they may be pared to a proper thickness. The back of your book being divided, with a pair of compasses, into seven compartments, allowing a large one for that next the tail, proceed to put on the lettering piece by cutting a piece of the thin morocco of the proper size, and, paring its edges on the paring stone with a very sharp knife, and having pasted it well, apply it to the back and rub it well into contact, by laying a piece of paper over it, and rubbing it well down with the folding stick. It should have been remarked, that after dividing the back into compartments with the points of the compasses, in order to have a guide in rolling the bands on the back in finishing, a piece of paper, previously doubled many times, is laid across the back where the points of the compasses have marked, holding it down with the fingers and thumb against the sides of the book, and marking by its edge on the back with a folder. The book is now ready for gilding or, as it is called, *finishing*. The back and sides of the book are now to receive three coats of glaire, which is made by beating the whites of eggs, with about two drops of sweet oil to each, until they are quite thin; this is best done by splitting a small piece of cane or stick, six inches long, and putting through it, at right angles with it, bits of quill; by immersing this in the cup, and rolling it round briskly between the palms of the hands, the eggs will soon lose their ropiness and be fit for use. Let each coat dry before another is put on. When the last coat of glaire is dry, rub the back with a greasy or oily rag; and having laid a sheet of gold on the cushion, and divided it into strips sufficient to cover the back, lay the back on it gently, and the gold will attach to it; then turn the back up, and press it into contact with a little cotton wool.

As the handling of gold is a matter of great nicety, and requires a great deal of practice to do it well, we shall describe the proper manner as near as possible, and give such cautions as are necessary. Books of gold contain 20 leaves, and that sort which is used by binders, is called deep gold, except for gilding the edges of books or paper, when pale gold is often used, being somewhat cheaper. Lay the book of gold on the cushion, and open with the left hand the first leaf, about half way, by doubling back the first paper leaf, pressing at the same time with the fingers of the left hand to keep the other parts of the book still; then blow gently against the fore-edge of the book of gold, which will cause the first leaf of gold to rise and turn itself back on the half leaf of paper, the other part of the leaf of gold being kept firm by the remainder of the leaf of paper; you must now place the gold knife flat on that part of the book from which the gold was blown, by blowing in a contrary direction, so as to drive it into its former situation; the knife now being under it, the paper is to be removed and the gold raised on the knife, and floated gently through the air by waving the hand, and deposited flat on the cushion. You must avoid touching the gold or the knife with the hand, as the least grease will cause it to stick. After the gold is placed on the cushion, to cut it, you must first place the edge of the knife firmly and steadily on the gold without drawing it either way, then draw the knife once forwards and backwards keeping it in the same direction and pressing

pressing pretty hard on it, this will divide the gold without crumpling it.

When the book is to be full gilt, or what is termed *extra*, it is common to gild the back all over in the manner before described, and work the tools on it; but when it is to be less finished, called calf neat, or *half extra*, the lettering piece alone is covered with gold, and the bands rolled by laying, or rather taking up on the roll, strips of gold, by rubbing the edge of the roll when hot all over with the oil rag, and pressing it gently on the gold, which is previously cut to the proper width on the gold cushion. The proper degree of heat which the tools ought to be of, is generally known by wetting the finger in the mouth, and applying it to the tool; if it frizz a little while, it is considered a proper heat, but if the spittle suddenly run off, or dissappear, the tool is too hot; it must however be allowed that this is a very vague manner of judging, and a little experience is the only mode by which it is to be ascertained.

In lettering books, which is the first thing done towards finishing, screw them in the cutting press with their heads from you, and the tail inclining a little downwards; and having fixed on the words, select the letters and place them to the fire, seven or eight at a time; you must now consider how far asunder they ought to be kept, so as to fill the line, take then two or three of the letters from the fire, and having ascertained whether they are of a proper heat, rest the elbow of the left hand on the press, leaning the body forward over the book, raising the left hand, so as to steady the right which grasps the letter, then breathe on the gold, and firmly imprint the letter in its proper place. You may mark the line as a guide, to keep the letters straight on the lettering piece, previously to laying on the gold; but this is only necessary for beginners. All the back tools and pallets are used in the same manner as letters.

The manner of using the rolls, is too obvious to require any other instruction, than what has already been given.

The gold is now to be cleaned away by rubbing it with an oil rag, which done, it must be polished with the polishing iron. This tool is a round piece of iron, 4 or 5 inches long, a little swelling in the middle, and polished on one side, out of the upper side proceeds a spill, to which is affixed a long wooden handle, which, when used, rests against the shoulder; before used, it is heated pretty warm and rubbed upon an old leather back, on which some fine ashes are occasionally thrown, to clean and polish it; in this state it is rubbed over the back and sides of the book, which require to be lightly touched with the oil rag, during the operation. Extra work is sometimes pressed again between horns, which gives it a more exquisite polish.

MISCELLANEOUS OBSERVATIONS.

All stationary work is sewn with strong waxed thread, and as the vellum or parchment is never attached to the back like leather, but lies hollow and loose when the book is open, it cannot of course afford that security to the back, which leather does: it is therefore common to line the back between the slips, with coarse canvas or slips of leather, letting them come as much over the sides, as to paste down with the boards and slips. The boards for stationary are not so thick in proportion as for printed work, and, when put on, are placed at least half an inch from the back. On each side the parchment slips which books are sewn upon, you must cut with scissars a very narrow strip, which is not to be pasted down, but left for the purpose of drawing through the parchment when the cover is applied, and serving to attach the cover, before it is pasted to the boards. Parchment or Vellum covers should always be lined before they are put on, and applied before they are quite dry. The edges of stationary work are most commonly sprinkled, and not burnished; but printed books, whether sprinkled or coloured, are burnished with a dog's tooth, or agate, set in a long handle, and the leaves of the book being screwed tight between boards in the cutting press, are rubbed over with them till they have acquired a gloss.

In warm weather, gild but a few backs at a time before finishing, otherwise they will get too dry.

All extra binding is rolled round the sides of the cover, both within and without, and the head-band is generally a double one; it is also usual to put a register of coloured ribbon, which must be pasted in before the leather back is put on. It is now very common to give an artificial kind of grain to the backs of russia and calf books; this is done by pressing them between boards, cut for the purpose.

Russia leather, being harsh, should be well soaked for half an hour in water, and beat, and rolled, before used.

Morocco, requires less glaire for finishing than other leather, and is only rubbed well with a piece of rough calf skin. Polishing with the polishing iron, spoils the grain and destroys its colour.

Rough Calf books are finished with hot tools without gold; the tools should be heated a little hotter for the purpose. Keep your gold free from damp, as it spoils it.

A charcoal stove, similar to that used by tinmen, is preferable to a coal fire, as the letters and tools suffer less from the former than the latter; another advantage is, that it may be placed near the work.

In rolling the bands on the back, the book should be held against a board, which is screwed firmly in the cutting press, and projecting nearly the height of the book above it.

All extra books have marble paper at beginning and end, besides blank leaves, which when pasted to the cover, is rubbed into the joint neatly, and suffered to dry whilst the book is open.

Before

Before gilding russia leather, wash the cover once with serum of bullocks blood; this gives it a proper gloss, and prepares it better for receiving the gold.

Calf should be glaired three times, and sheep twice, before gilding or polishing.

When quarto plates are to be put into an octavo book, the plate should be neatly doubled in the middle, with its face inwards, and a small slip of paper about an inch wide, affixed to the back, half of which is pasted to the front, and the other half left projecting beyond it, to affix it to the book; this is called guarding.

As it sometimes happens, that port-folios for prints are wanted of a larger size than paste-boards are commonly made, the way to obviate this difficulty is to make each cover of two layers of boards, by bringing the joints of one layer, over the middle of the boards which form the other layer, or as it is called by bricklayers and masons, breaking the joints: by this contrivance, boards may be formed of any size required. You must lay the boards on an even floor whilst they are drying, placing paste-boards and other heavy substances on them, as they are of course too large for the press.

A very good kind of paper for covering memorandum and copy books, may be made by mixing with paste any cheap colour, and going over any printed or waste paper with it, then with a comb or piece of flat wood broken across the grain, wave it over the colour, and hang it up to dry. In boiling paste, add a little pounded alum to the flour and water before you boil it; and always boil it as thick as you can, as it keeps much better, and can be thinned by adding water as you want it.

Always keep good old glaire for finishing, as it produces better impressions of the tools, and gives the gold a better colour.

It is a proper thing to keep a second plough, with an old knife in it, for cutting the paste boards, otherwise your knife will never be in order, and will cut the edges rough.

Mix a little paste with your common colours, for sprinkling and colouring the edges, to bind them.

Too much attention cannot be given to the quality of the thread for sewing the books; to be good, it should be strong and not too hard twisted, which common threads generally are. Keep thread and silk always well secured from the air. Sometimes raised bands are put on books, which have been sewed for flat or fair backs, this is best done by slips of paste board, or vellum, many times doubled, cut in square slips, and glued to the back: which gives a very neat effect, if the sharpness and squareness of the artificial bands is preserved after the leather is put on, particularly if the bands are given a different colour from that of the back, and tooled neatly. Sometimes head-bands, instead of being round, are square; the same materials are made use of for them, as for the bands of backs. In half bound books, parchment corners are preferable to leather ones, as they resist blows better, and are less troublesome. Before lining your parchment covers for stationary, spunge them with water and lay them one on the other, with a weight on them to soften.

INSTRUCTIONS FOR MARBLING AND SPRINKLING THE SIDES OF BOOKS.

Let the book be put between two wands or slips of wood, with their ends resting on boxes or any other thing that will keep the books at a sufficient or convenient height from the floor, inclining the book in any way that you would have the marble run, which will ever follow the direction that the book is inclined to; but should it be wished that the marble be of the tree kind, having a centre or stem, it is easily done by bending each side of the book in the middle, forming a kind of shoot or gutter, so that the water or colour being thrown on, runs first from the sides to the centre, and then through this gutter to the tail of the book, forming a marble somewhat resembling a tree. Let a sufficient quantity of each colour be taken out of the bottles, in open cups, with a common painters dusting brush for each, of a size proportioned to the quantity of colour required; provide also a large pan of clear water, with a large piece of sponge in it for washing away the colours when they have remained a sufficient time on the cover. Every thing being thus prepared, throw on water with a bunch of quills tied together by the feather ends into a kind of brush, in large splashes, by dipping the quills in the water and knocking them gently against the iron press pin, which is held in the left hand, then take a small quantity of any of the colours as hereafter directed, on your brush, and having knocked out the superfluous colour by striking it lightly against the press pin, holding it over the cup, from which you took it, then hold the press pin over the book, and strike the brush, so as to let the colour fall in a kind of rain on the cover of the book; and so proceed with all the colours, following the one upon the other as quick as possible, that the whole may run together: then with the sponge and water wipe them lightly over, and stand them on their ends to dry.

If the book is to be spotted or sprinkled, it should be kept flat, not inclining either way: but should you wish to have it splashed or mottled, a small degree of inclination may be given to the book, to induce the colours to run together, which sometimes has the happiest effect.

To sprinkle the sides or edges of books the process is the same, having a stiff hair brush cut off square at the ends: you dip it in the colour, and holding it in the left hand, rub over the ends of the brush the folder or ivory knife, this causes the colour to fall on in fine or coarse spots according as the

To

brush is more or less charged with colour.

Let your brushes and sponges be always used for the same colour, and never add spirit to colours till they are about to be used. Always wash out the brushes and sponges in pure water after using, otherwise they will be soon destroyed.

RECEIPTS FOR MARBLING AND STAINING THE BACKS AND SIDES OF BOOKS.

Black. Boil half a pound of copperas, in two quarts of soft water; when a good black and settled, put it into a clean bottle for use.

Brown. Half a pound of the best potash, dissolved in one quart of rain water, and when clear bottle it for use.

Vitriol water. One ounce of the best oil of vitriol, mixed with three ounces of water; boil it for use.

Vinegar black. Steep iron filings in vinegar or table beer, for twenty-four hours; then give them a quick boil on the fire, and when settled, strain and bottle the liquid for use.

Dark sprinkle. Wash the cover of the book with a sponge and very weak potash water, and immediately place it between wands or sticks, letting the leaves of the book drop between them, whilst the covers remain extended flat, and sprinkle them very fine and dark with the copperas.

Another beautiful sprinkle may be done by giving in addition to the dark sprinkle, a sprinkle of brown and vitriol water.

Common marble. Wash the cover with weak potash water, and give it a coat of glaire made with whites of eggs: when the cover is dry, put the book between the wands, throw on water, with a bunch of quills, in all directions, and immediately sprinkle with the copperas water and brown; let the marble remain a few minutes, and then wash it with a clean sponge and water.

Another marble. Wash the cover with strong potash water; glaire it, throw on water, use the vinegar black, and lastly throw on a fine sprinkle of vitriol water, which will be a great addition to the marble.

A marble in the form of trees may be made by bending the boards in the centre, after their being glaired and washed as before directed.

Red spots. Aqua regia. Mix, in a quart bottle, two ounces of the best double aqua fortis; one table spoonful of spirits of salts; half an ounce of grain tin, and four ounces of rain water. The whole must remain twenty-four hours before using.

Black the cover of the book with copperas water, and when dry give it a coat of brazil red. Mix a little aqua regia and dry brazil together, and when settled, spot the cover, when between the wands, with the red liquid. When the spots are perfectly dry, wash the cover with a sponge and water.

Yellow spots. Black the cover of the book, and when dry, put it between the wands. Mix aqua regia and turmeric together, and when settled throw on large, or small yellow spots.

Red and Yellow spots. Black the cover, throw on the yellow spots, and when dry, throw on small spots of liquid red. Wash the cover with a clean sponge and water. Mix no more colours with the spirit than what are wanted for immediate use, as it destroys the colour.

Transparent marble. Marble the boards of the book with a tree down each centre, place it between the wands, and put on each board an oval, made of a thin piece of press paper, with a piece of lead on each. Black the cover on the outer parts of the oval, and when dry, go over the same with strong brazil water. Throw on red spots, let them dry, then remove the ovals; wash the cover, where the red spots are, with a clean sponge and water. Colour the inside of the oval with the following liquid, which will have a beautiful effect. Mix an ounce of spirits of wine and a table-spoonful of powdered turmeric together, in a bottle; shake the liquid well, and let it settle before using.

Give the ovals two fine coats of the liquid, with a camel's hair brush, and when done, cork up the bottle to prevent evaporation.

Egyptian marble. Before covering the book, colour the leather with Scott's liquid blue, and immerse in water, to extract the spirit. When the cover has been half an hour in the water, take it out and lay it between pieces of brown paper till almost dry. Cover the book, place it at a little distance from the fire till perfectly dry, and glaire it. Put the book between wands, throw thereon potash water with a bunch of quills, and, lastly, a fine sprinkle of the vinegar black. The book must remain till nearly dry, and be washed with a sponge and water.

Purple marble. After the book is covered and dry, colour the cover with strong hot purple liquid, two or three times. Glaire the cover when dry, and put the book between wands; throw on water with quills, and sprinkle it with strong vitriol water, which will produce bright red veins. After the colours are dry, wash them with a sponge and water.

Stone marble. Glaire the cover, and when dry, put the book into the cutting press with the boards sloping, to cause the colours to run gently down. Throw on copperas water freely, with a brush, dip a sponge into the strong potash water, and press it out on different parts of the back, so that the colour may run down each side; where the brown has left a vacancy, apply vitriol water in the same manner. Let the book remain till the colours are perfectly dry, then wash the cover.

Rice marble. Colour the cover with spirits of wine and turmeric, put the book between wands, and throw on rice very regular. Throw on a fine sprinkle of copperas water, till the cover is nearly black, and let it dry. The cover may be spotted with red liquid or potash water, before the rice is thrown off.

Chinese marble. Colour the cover of the book with a dark brown, and put it between wands; mix

 whiting

whiting and water of a thick consistency, and throw it on in spots or streaks, which must remain till dry. Spot or sprinkle the cover with liquid blue, and lastly, throw on large spots of the liquid red. The colours must be dry before washing off the whiting.

Another marble. Black the cover with copperas water, let it dry, and give it two coats of strong brazil water. Throw on whiting as above-mentioned, and give the cover a bold sprinkle with the red liquid.

Red marble. Before covering the book, it will be necessary to spunge the cover well with lime water, and dry it in brown paper.

Boil, on a slow fire, one ounce of brazil dust; a tea-spoonful of powdered cochineal; a little alum, and half-a-pint of the best vinegar, till the whole produce a bright red.

Colour the cover two or three times over, while the liquid is hot, and then immerse it in alum and water, previously dissolved. Cover the book in the usual manner, and let it be perfectly dry. Glaire the cover, and put the book between wands; throw on potash water with quills, and sprinkle with vinegar black.

A few drops of aqua regia may be put into the liquid before colouring the cover, which will give it a brighter and more permanent red.

Wainscot marble. Colour the cover with strong brown, glaire it, and place the book in the cutting press or wands, having the boards flat and even. Throw on water till every part of the boards is covered. Take a sufficient quantity of copperas water in the brush, and dash it on the boards freely; do the same with potash water, and lastly a bold sprinkle of vitriol water. This marble will have a fine effect, when great attention and care is paid thereto.

Japan colouring. After the book is covered and dry, colour the cover with potash water, give it two good coats of brazil wash, and glaire it. Put the book between wands, allowing the boards to slope a little. Dash on copperas water, then with a sponge full of liquid red, press out on the back, and on different parts, large drops, which will run down each board, and make a fine shaded red. When the cover is dry, wash it over two or three times with brazil wash, to give it a brighter colour.

Green shade. In addition to the stone marble before mentioned, use Scott's liquid blue in the same manner as the other colours, before finishing the marble with vitriol water.

In every recipe for marbling, be careful to let the colours have time to dry, as they then will have their full effect, and shew their brightness to great advantage.

When the backs are intended to be of one colour, which is very fashionable, and shews the gold to the greatest advantage, a piece of thin pasteboard must be put thereon, previous to marbling, colouring, &c. which will prevent the backs receiving any colour.

The following will be found to answer that purpose.

Green. Colour the back twice with Scott's liquid blue, when dry, wash it two or three times with sponge and water.

Purple. Rub the strong purple wash well on the back, near the fire, three or four times, and wash it, when dry, with clear water.

Blue. Colour the back with copperas water, and give it two coats of liquid blue.

Brown. Colour the backs with strong potash water.

Lead colour. Colour the back with very weak copperas water, or give it a coat of copperas and potash water mixed.

The backs being so coloured, there will be no occasion for coloured lettering pieces, or pieces for the number of volumes. All these are laid on with a sponge.

RECEIPTS FOR COLOURING EDGES OF BOOKS, &c.

Blue. Two ounces of fine powdered indigo, dissolved in two ounces of double oil of vitriol, and a tea-spoonfull of spirits of salts.

This liquid must be kept in an open earthen vessel, and remain for a week before it is used; when a little is reduced with water, it will make a beautiful sprinkle for the edges.

Green. Two ounces of French berries, and a little alum, boiled in a pint of rain water for an half an hour. Strain the liquid through a fine piece of flannel, and add a little of the liquid blue.

The green must be kept in a glass bottle, well corked up, and used for sprinkling, or colouring the edges with a sponge.

Purple. Half a pound of logwood chips; two ounces of powdered alum; and a small piece of copperas; boil them in three pints of soft water, till reduced to two, and strain the liquid. This purple will be found a cheap colour for sprinkling common work.

A fine purple for immediate use, may be obtained from strong potash water and brazil dust. Should any of the colour remain unused, it will, in a few hours, change to a brown.

Orange. Two ounces of brazil dust; one ounce of French berries bruised; and a little alum; boil them to a pint of soft water, and strain and bottle the colour for use. This colour may be spotted on the edges, to fancy, with other colours.

Brown. Boil in rain water equal quantities of logwood and French berries; and to give the colour a darker shade, add a little copperas; when it is cool, strain and bottle it for use.

Red. Half a pound of brazil dust, and two ounces of powdered alum; boil them well in a pint of vinegar, and a pint of water, till reduced to a pint; strain it through a fine cotton cloth. This liquid red will be of great use for sprinkling and spotting the edges, together with brown and purple.

Gold

Gold sprinkle. Put into a marble mortar, half an ounce of pure honey, and one book of gold leaf; rub them well together until they are very fine: add half a pint of clear water, and mix them well together; when the water clears, pour it off and put in more, till the honey is all extracted, and nothing remains but the gold.

Mix one grain of corrosive sublimate, with a teaspoonfull of spirits of wine, and when dissolved, put the same, together with a little thick gum water, to the gold, and bottle the liquid for use.

The edges of the book may be coloured or sprinkled, with blue, green, or purple; and lastly, with gold liquid, in small or large spots, shaking the bottle before using. Burnish the edge when dry, and cover it with paper. This gold sprinkle, will be useful for extra binding. Ladies may also use it for ornamenting their fancy works, putting it on with a pen or camel hair pencil, and burnishing it with a dog's tooth.

Rice marble. When the fore edge of a book is cut, let it remain in the press, and throw on rice in a regular manner, sprinkle the edge with any dark colour, till the white paper is covered, then shake off the rice. Various colours may be used, the fore edge may be coloured with yellow or red, before using the rice. By laying any other substance instead of the rice, so as to obstruct the sprinkled colour, various effects may be produced.

Fancy colouring. Let the book remain in the press when cut on the fore edge; mix whiting and water to a thick consistency, and with a small brush, throw it on the edge, in spots or streaks; when the whiting is almost dry, spot the edge with blue, green, purple, and brazil red. When quite dry, shake off the whiting, and brush the edge with a soft brush. A sprinkle of dark blue thrown on immediately after the whiting, will produce a beautiful shaded edge.

Water marble. Provide a wooden trough, two inches deep, and six inches wide. Pour hot water in it till nearly full, and put therein three ounces of gum dragon, which must be dissolved before marbling. Grind the following colours on a marble slab, with old ox gall, very smooth and fine, and procure a small brush and cup for each.

Prussian blue.
King's yellow.
Rose pink, or lake.
Flake white.
Lamp black.

Green.—Blue and yellow.
Orange.—Red and yellow.
Purple.—Blue and red.
Brown.—Black and yellow.

To prevent the water entering the leaves of the book, tie it tight between cutting boards of an equal size. Place the trough in a steady situation, and throw on the colours with their respective brushes, beginning with the blue, or any dark colour, and so on till the surface of the water is covered. The colours may remain in this situation, or be waved with a small iron pin. Hold the book with the edge downwards, and press it even and lightly with the colours, and it will immediately be marbled. Two or three colours only may be used, or as many as the marbler may think proper.

Should any of the colours not swim well, which is seldom the case, a few drops of spirits of wine may be added.

Soap marble. The following is a recent discovery, by very simple means, and may be used for marbling stationary book-edges, or sheets of paper for ladies fancy work.

Grind, on a marble slab, prussian blue, with a little brown soap, and water, to a fine pliable consistency, that it may be thrown on with a small brush.—Also king's yellow in the same manner, with white soap.

When green is intended for the ground colour, grind it with brown soap, and have king's yellow with white soap. Lake may be used for a ground colour, and prussian blue ground with white soap.—Brown umber for ground colour, and flake white ground with white soap. Any colour of a light substance may be used for marbling.

Marbling. Pour hard clear water into any vessel, large enough for marbling; throw on large spots of prussian blue, till the surface of the water is nearly covered; then throw on king's yellow, in small spots, which will immediately run into streaks or veins in all directions.

When marbling book edges, tie the fore edge &c. between boards before rounding the back, and press it lightly on the surface of the colours, which will make a beautiful marble, and burnish well if required.

In like manner, all colours as above mentioned, will have the same effect, provided the ground colour, (that is), the colour thrown in first, be ground with brown soap, and that for the veins with white soap.

Sheets of good strong paper may be marbled for ornamenting fire screens,&c. or a thinner kind for half bound books. without any preparation whatever, except a vessel large enough to receive the sheets, and putting them on in a careful manner, that the whole may receive the colours.

Gilding vellum.—Glaire the cover once, let it be perfectly dry, and rub it over with the oil rag, where the gilding is intended to be. Make the roll hot, and work it firm and strong, to make a good impression.

Gilding paper and book edges.—With the white of an egg, mix twice that quantity of water; a tablespoonful of bullocks blood, taken from the top, when it has settled some time; beat them well together for an hour, let the whole stand three days before using. The paper must be well pressed, and when cut,

cut, made very smooth with a piece of glass, or an iron scraper. Put the gilding boards even, on each side of the paper, and screw it tight in the cutting press. With yellow ochre, and gold size mixed together, colour the smooth edge, rub it till it is quite dry, with paper shavings, and burnish the same with the dog's tooth. Cut the gold leaf, and with a thin piece of paper, previously rubbed on your forehead, to induce the gold to adhere, press it on the gold gently, which will attach itself to the paper, and proceed until there is sufficient to cover the edge. With a camel's hair brush float the edge with a gilding size, hold the paper on which the gold is, with the fingers of each hand, and lay it gently on the size. When the whole is covered, let the superfluous size run from under the gold, by inclining the press; stand it a little distance from the fire, till dry; to ascertain which, breathe on the gold, and if it immediately becomes bright, you may conclude it is ready for burnishing.

Red Ink.—Half a pound of brazil dust, half an ounce of powdered cochineal, a piece of lump sugar and four quarts of vinegar. Let them steep for twelve hours, and boil them on a slow fire till you have a good red. When the ink is settled, strain it through a piece of fine cotton, and bottle it for use.

Slate paper.—Boil glue and water to a good consistency, and when on the fire, add lamp-black, and fine powdered emery. Give the paper two coats of the liquid with a fine brush.

Splash paper.—Before colouring the paper, it will be necessary, in the first place, to prepare the proper colours, and have them bottled for use. They must also, after being boiled, be steeped for twelve hours, in their respective quantities of water and vinegar, as follows:—

Purple.—Half a pound of logwood chips, with vinegar and water, each half a pint.

Dark red.—Half a pound of brazil dust, with vinegar and water, each one pint.

Bright red.—Before colouring, put a few drops of aqua regia into a small quantity of the dark red.

Green.—Half a pound of French berries, bruised; water and vinegar, each one pint, with two ounces of liquid blue.

Brown.—Two ounces of strong potash water, with one ounce of brazil dust, which must not be boiled, but remain till the colour change from a light purple, to brown.

Yellow.—Half a pound of French berries, water and vinegar, each one pint.

The above colours must have a small quantity of alum bruised, put therein, and boiled over a slow fire. Strain them through a piece of fine flannel, or cotton cloth, till quite pure.

Dissolve half a pound of alum in two quarts of rain water; sprinkle it on the sheets of paper for colouring, and lay one upon another. Put the paper between boards, with a little pressure thereon, and leave them to soak for five hours before splashing.

Purple splash.—Place small stones at a little distance from each other, and lay the sheet thereon; throw on with a brush, purple liquid in splashes.

Tortoise shell.—Splash on black ink, and throw on dark red, and yellow spots where the paper is white. Various other combinations may be formed by using different colours.

To colour vellum green. Dissolve an ounce of verdigrise, and an ounce of white wine vinegar, in a bottle, and let them remain near the fire for five days, shaking the bottle three or four times each day. Wash the vellum over with weak potash water, and colour it over three times with the green liquid.

BREWING.

Brewing is the art of making porter, beer, or, ale. This art is undoubtedly a branch of chemistry, and depends on fixed and invariable principles. Those principles not having been thoroughly investigated, no just and certain theory has yet been obtained. We shall, however, insert the best rules which practical observations and experience have hitherto laid down.

Malt liquor is essentially composed of water, and the soluble parts of malt and hops, fermented with yeast.

Of water. Lightness is considered as a perfection in water, that which weighs least, being generally the purest. In brewing, the difference of water, whether rain, spring, river, or pond, is of little importance, provided it be equally soft and pure; the chief art consists in the due regulation of heat; and as soft waters are found in most places, and become more alike when heated to the degree necessary to form extracts from malt, it is evident, that any sort of beer or ale may be brewed with equal success, in all places where malt and hops can be procured.

Of Malting.—Malt is barley rendered fit for the purpose of brewing, by being made to sprout or germinate with degrees of heat nearly equal to those which the seed should be impressed with, when sown in the ground: and dried with a heat superior to that of vegetation, and capable of checking it. The barley is put into a cistern that holds five, ten, twenty, or more quarters, and covered with water about five inches, to allow for its swelling; it should remain in the cistern two or three days, more or less, in proportion to the heat of the air, and the state of the barley: that which has been washed by rains, requires less time than the dryer grain that was saved well, and grew on dry ground. To judge when the corn is fully saturated, some persons drop an iron rod perpendicularly into the cistern; if the grain readily gives way, it is then considered time to draw off the water. Others take some of the corns, endways, between their fingers, and gently crush them; if they are in all parts mellow, and the husks open, or start a little from the body of the corn, they conclude it has soaked long enough. The nicety of this is a material point; for if it is infused too much, it will lessen the sweetness and the spirit of the malt, and cause the beer or ale made from it, to become dead and sour in a short time.

The water being well drained off, the grain should be taken out of the cistern, and laid in a heap, about two feet in height. The corn should not be suffered to acquire so great a degree of heat in this heap, as to carry on germination too fast, for this would cause the malt to become bitter and ill tasted. Before the acrospire is perceived to lengthen, the barley must be dispersed in beds, on the floor of the malt house, and be turned every four, six, or eight hours, the outward parts inwards, and the bottom upwards, always keeping a clear floor, that the corn, which lies next it, may not be chilled. As soon as it begins to come, or spire, it should be turned every three, four, or five hours, according to the temperature of the air, (by which this management ought to be governed;) as it comes or works more, the heaps must be spread wider and thinner, in order that it may cool. Thus it may lie, and be worked upon the floor, two or three feet thick, ten or more feet broad, and fourteen or more feet in length, to chip or spire; and when it is come enough, it is to be turned twelve or sixteen times in twenty-four hours, if the season is warm. When it is fixed and the roots begin to die, it must be thickened again, and often carefully turned and worked, that the growth of the root may not revive. The floor should be kept clear, and the malt turned often, that it may neither mould nor acrospire; *i. e.* that the blade may not grow out at the opposite end to the root; for if it does, the strength of the malt will be destroyed.

It is of great consequence in making of malt, that the grain be dried by a very slow and gradual heat; for this purpose it should be thrown into a large heap, and there suffered to grow sensibly hot; in this active condition, it is spread on the kiln, where it is exposed to a heat greater than is necessary for vegetation, by which its further growth is stopped. The time usually allowed for drying a kiln of malt, is from eight, to twelve hours. When the colour of the barley has not been greatly changed by the heat, it is called pale malt; in proportion to the degree of heat it has been exposed to, the deeper will be the colour, each shade being distinguished by a different name, as brown malt, amber malt, &c. Malt when sufficiently dried, must be taken from the kiln and spread in an airy place till it is thoroughly cool; and then put into a heap. When malt is suffered to grow too much, or until the spire has shot through the skin of the barley, though all that is left be malt, it is not fit to brew drinks for long keeping. Some maltsters sprinkle water on malt newly removed from the kiln, to make it appear to have been made a long time, or, as they say, to plump it; this is a deceit which

cannot be too much exposed, as by this practice, the purchaser is grossly imposed on. The grain by being moistened, occupies a greater volume, and soon grows mouldy, heats, and is thereby greatly injured.

There are several contrivances made use of for the purpose of drying the malt on, as the iron plate frame, and the tile frame, which are both full of little holes; the brass wired and iron wired frames, and the hair cloth. The iron and tiled frames, were chiefly invented for drying brown malt, and saving of fuel; these, when thoroughly hot, will scorch the corn in a short time. The wire frames are better, yet they are apt to scorch the outward part of the corn, which cannot be got off so soon as the hair cloth admits of. The last three ways are much used for drying pale and amber malts, because the malt can be more gradually dried; but the hair cloth is considered the best of all.

Malt is dried with several sorts of fuel, as coke, culm, Welch coal, straw, wood, fern &c. Coke is considered the best, if properly made, because it does not send forth smoke to injure the flavour of the malt. Some persons put a peck or more of peas with every five quarters of barley, to be made into malt, which greatly mellows the drink: beans will do so likewise, but they will not come so soon, nor mix so conveniently with the malt as peas.

Oats malted in the same manner as barley, will make a weak, soft, mellow, and pleasant drink; but wheat, so treated, will produce a strong, heady, nourishing and fine liquor.

To know good from bad malt, examine if it has a round body, breaks soft, is full of flour, smells well, and has a thin skin; chew some of it, and if you find it sweet and mellow, it is good. If it be hard and steely, and retains something of the nature of barley, it has not been rightly made, and will weigh heavier than that which has been properly malted.

Pale malt is the slowest and slackest dried of any; and will produce a greater length of wort than the brown high dried malt; for which reason it is sold for two, three, and four shillings per quarter more: it is of all others, the most nutritious, being the most simple, and nearest to its original barley-corn; and will retain an alkaline and balsamic quality much longer than the brown sort.

Amber-coloured malt is dried in a degree between pale and brown; and is much in use, though but seldom used alone.

Brown malt is the highest dried, and will not admit of as much wort being drawn from it as pale and amber malt.

According to Mr. Combrune's statement, 120 degrees is the lowest heat for drying pale malt, and 150 the highest for brown malt; and he assumes it as a principle, that the heat of the extracting liquor should be in proportion to that with which the malt was dried.

When the exciseman takes his gauge on the floor, he allows ten in the score; but at times he gauges in the cistern, couch, floor, and kiln; and where he makes most, there he fixes his charge.

Of Grinding.—It is necessary for malt to be ground, in order to facilitate the action of the water on the grain, which otherwise would be obstructed by the outward skin. Every corn should be cut, but not reduced to flour or meal, for in this state the grist would not be easily penetrable; it is therefore sufficient that every grain be divided into two or three parts. In every brewing, the intention of grinding is the same; and the transparency of the liquor does not depend on the cut of the corn, as is supposed by many persons. It has been recommended to bruise the malt between two iron cylinders, instead of grinding it: if by this means, some of the fine mealy parts are saved, which would otherwise be lost in air, it must be very inconsiderable, and perhaps not equal to the disadvantage of the water not coming in immediate contact with the flour of the grain, so that, upon the whole, the difference between bruising and grinding the grain can be of no great consequence.

The constituent parts of malt, like those of all vegetable sweets, are so inclined to fermentation, that, when once put in motion, it is difficult to retard their progress, retain their preservative qualities, and prevent their becoming acid. Among the many means put in practice, to check this forwardness of the malt, none promised so much success as blending with the extracts, the juices of such vegetables as of themselves, are not easily brought to fermentation. Hops were selected for this purpose, and experience has confirmed their wholesomeness and efficacy.

Hops are an aromatic, grateful bitter, endued with an austere and astringent quality, and guarded by a strong resinous oil. The aromatic parts are volatile, and disengage themselves from the plant with a small heat. To preserve them in the processes of brewing, the hops should be put into the copper as soon as possible, and be thoroughly wetted with the first extract, while the heat of the wort is at the least, and the fire under the copper has little or no effect thereon; by this means that flavour is retained which would otherwise be dissipated.

After hops are bagged, the sooner and tighter they are strained, the better they will keep. If in brewing, part of a bag or pocket be left unused, let the upper part of the bag be covered close over the remainder, and a heavy weight put upon it, to exclude the air.

Of mashing.—The first step in the process of brewing, is mashing, which is performed in a large circular wooden vessel, called a tun, shallow in proportion to its extent, and furnished with a false bottom, a few inches above the real one, pierced with small holes, and made either moveable or fixed. There are two side openings in the interval between the real and false bottom, to which pipes are

are fixed, one for the purpose of conveying water into the tun, and the other for drawing the liquor out of it. The malt is to be strewed evenly over the false bottom of the tun, and then, by means of the side pipe, a proper quantity of hot water is introduced from the upper copper. The water rises up through the malt, or, as it is called, the grist, and when the whole quantity is introduced from the upper copper, the mashing begins, the object of which is to effect a perfect mixture of the malt with the water, so that the soluble parts may be extracted by it; for this purpose the grist is incorporated with the water, by means of iron rakes, and then the mass is beaten and agitated by long flat wooden poles, resembling oars, which are either worked by hand or machinery. When the mashing is completed, the tun is covered, to prevent the escape of heat, and the whole is suffered to remain at rest for some time, in order that the insoluble parts may separate from the liquor; the time it is allowed to remain still, is various, according to the nature of the liquor to be brewed, and is called the standing of the mash. The side hole is then opened, and the clear wort allowed to run off slowly at first, but more rapidly as it becomes fine, into the lower or boiling copper.

Many ingenious machines have been invented for the purpose of mashing; we shall give a description of two, which we conceive the best, one of which was invented by Mr. Goodwynne, the other by Mr. Silvester.

Mr. Goodwynne's mashing engine is of the figure of a half cylinder, with the central line placed horizontally. In this central line, an iron shaft is fitted, and turned round by wheelwork from a steam engine. It has several iron arms fixed perpendicularly upon it at different parts of its length, which, as the shaft revolves, sweep the whole contents of the tun, and having teeth fixed in them, mash the grist. These arms are not all fixed on the same side of the axis, but are arranged at equal angles round it, so as to dip in succession. When by their continual motion the grist is accumulated at one side of the tun, the motion of the shaft is reversed, and this brings the grist back again.

Mr. Silvester's machine, consists of a vertical spindle, in the centre of the mash tun; and upon this an iron arm, of a length sufficient to extend across the diameter of the tun, slides up and down, through the grist. The arm is provided with teeth, projecting from one side of it like a rake; and these teeth are so contrived, that when the arm descends, they hang down vertically; but when the arm reaches the bottom of the tun, the teeth are turned by the machine, so as to be horizontal, and are then drawn up, during which action they raise a portion of the grist from the bottom to the top. The next time the arm descends, it is turned round with its spindle, a few degrees, so as to take a fresh portion of the tun; and in this manner its action continues, till in about 30 or 40 strokes it completes its revolution round the tun. This construction admits of the mash tun, being covered close over by large doors, a circumstance of great importance for retaining the heat.

The chief thing to be attended to in mashing, is the temperature of the mash, which depends on the heat of water, and on the state of the malt; if the water was let in upon the grist boiling hot, the starch which it contains would be dissolved, and converted into a gelatinous substance, in which all the other parts of the malt, and most of the water would be entangled beyond the possibility of recovery. The most eligible temperature for mashing appears to be from 185° to 190° of Fahreneit; for the first mashing, the heat of the water must be somewhat below this temperature, and lower in proportion to the dark colour of the malt made use of; for pale malt, the water may be 180°, but for brown, it ought not to be more than 170°.* The wort of the first mashing is by much the richest in saccharine matter; but to exhaust the malt, a second and a third mashing is required, in which the water may be safely raised to 190° or upwards. The proportion of wort to be obtained from each bushel of malt, depends entirely on the proposed strength of the liquor. It is said that 25 or 30 gallons of table beer may be taken from each bushel of malt. For ale and porter of the superior kinds, only the produce of the first mashing, or six or eight gallons per bushel, are to be taken.

Of boiling and hopping. If only one kind of liquor is made, the produce of the three mashings are to be mixed together; but if both ale and table-beer are required, the wort of the first, or of the first and second mashing, is appropriated to the ale, and the remainder is set aside for the beer. All the wort distined for the same liquor, after it has run from the tun, is transferred to the large lower copper, and mixed with a certain proportion of hops. The better the wort, the more hops are required. In private families, a pound of hops is generally used to every bushel of malt; but in public breweries, a much smaller proportion is deemed sufficient. When both ale and table-beer are brewed from thesame malt, the usual practice is to put the whole quantity of hops in the ale wort, which having been boiled some time, are to be transferred to the beer wort, to be again boiled with it.

To preserve porter for twelve months, when fermented

* The process of brewing has within a few years been rendered much more certain by the use of the thermometer, to determine the degree of heat proper for mashing; and an instrument called a sacchrometer, to ascertain the strength and goodness of the wort. This last instrument is a kind of hydrometer and shews the specific gravity of the wort, rather than the exact quantity of saccharine matter which it contains.

mented at forty degrees, twelve pounds of hops are considered sufficient for the produce of one quarter of malt; but if heated to sixty degrees, rather more than double the quantity of hops will be required to preserve the beer the same length of time. For small beer to be fermented at 40 degrees, three pounds to the quarter will be sufficient; but at sixty degrees, it will require six pounds of new hops, or six and three-quarters pounds of old hops, which are such as have been kept one year, and have, in consequence, lost some of their good qualities; but this difference is not worthy of notice, when only small quantities are used.

When the hops are mixed with the wort in the copper, the liquor is made to boil, and the best practice is to keep it boiling as fast as possible, till upon taking a little of the liquor out, it is found to be full of small flakes like those of curdled soup. The boiling copper in common breweries, is uncovered; but in those on a very large scale, it is fitted with a steam-tight cover, from the centre of which passes a pipe, that terminates by several branches in the upper mashing or copper. The steam therefore produced by the boiling, instead of being wasted, is let into the cold water, and thus raises it very nearly to the temperature required for mashing, besides impregnating it very sensibly with the essential oil of the hops, in which the flavour resides.

Of cooling. When the liquor is boiled, it is discharged into a number of coolers, or shallow tubs, in which it remains until it becomes sufficiently cool to be submitted to fermentation. It is necessary that the process of cooling should be carried on as expeditiously as possible, particularly in hot weather, and for this reason, the coolers in the great brewhouses are very shallow. Liquor made from pale malt, and which is intended for immediate drinking, need not be cooled lower than seventy-five or eighty degrees; of course this kind of beer may be brewed in almost the hottest weather; but beer brewed from brown malt, and intended to be kept, must be cooled to nearly sixty degrees, before it is put into a state of fermentation. Hence, spring and autumn have been deemed the most favourable seasons, for the manufacture of the best malt liquors. In the summer, worts must be got as cool as the weather will admit of: and it being found, that about three o'clock in the morning is the coolest period of the twenty-four hours, this is the time that they should be set to work.

Mr. Jonathan Dixon has a patent for forming the various vessels in a brewery of cast iron. This metal seems very well adapted to the formation of coolers, as it allows the heat to pass off more readily than wood, is not liable to crack in hot weather, and is altogether free from the great repairs necessary to wooden ones.

Of fermentation. Beer receives its strength and spirit from the process of fermentation, during which a quantity of fixed air is given out of the fluid, the wort loses its viscidity and sweet taste; its specific gravity is diminished, and an inebriating quality is given to the liquor. When the wort is at a proper temperature, the yeast is added to it, in the gyle tun, or square, and in a short time the fermentation begins at the sides of the tun, and gradually advances towards the middle, till the whole surface is covered with a white scum, formed of small bubbles, which increase in size as the fermentation advances, forming a head of yeast. Some of the bubbles, on reaching the surface, burst, and the film of yeast which covered them sinks, but is again borne up by the ascending bubbles. These films form at first a yellow, and, as the process advances, a dirty, brown, uneven covering to the yeast, giving it the appearance of rocks. In this state the fermentation is at its crisis, and afterwards diminishes. When the head begins to sink, which it does first in the middle of the tun, the fermentation is to be checked by cleansing, that is, dividing it into small casks, and allowing any farther yeast which it may produce, to flow off as fast as it is formed; taking care to keep the casks filled up with fresh liquor, till this discharge ceases, when the bung-hole is to be closed; and the liquor, after having stood a sufficient time to fine, will be fit for use. In London, from the large capital required in the brewing trade, the brewers find it necessary to make a quick return, and therefore send the beer out in the rough, as they term it, that is, before it has stood a sufficient time to fine: in this case, a proper quantity of fining is sent with it, which is composed of isinglass dissolved in very sour beer, brewed on purpose, without hops, from a fourth mash. The innkeeper puts the fining into the cask, which mixes with the fecula floating in the beer, and forms a kind of net work, which gradually sinking to the bottom, carries all the impurities with it. Heat increases the violence of fermentation, and and if too great, the process advances so rapidly as to render it difficult to check it at the proper stage, which, if not effected, the acetic fermentation will commence before it has precipitated the mucilage, or in the brewer's language, purged itself, and cause an unpalatable mixture of acid, from the excessive fermentation; and of bitter, from the excess of mucilage. In the other extreme, where the heat is not sufficient for the fermentation, a decomposition of the wort takes place, and produces an unpalatable liquor, containing a combination of sweet and bitter. In strong pale ales, it is the object of the brewer to give them the greatest possible strength, together with a very clear and fine light colour, without containing much of vegetable flavour. In brown ales, and porter, a fulness of palate, deep colour, glutinous taste, and vegetable flavour are produced by retaining part of the farinaceous matter, instead of expelling the whole of it, as in the former instance.

When the heat of the atmosphere is more than sixty

sixty degrees, the cool of the night must be chosen, to put the wort to work. In lower degrees of the atmosphere, the wort must be set at a greater heat than that of the air; for as the tendency to fermentation increases with the heat of the weather, it is necessary to correct it, by putting the liquor to work colder, in hot weather, than in cold. If the air is at 30 degrees of Fahrenheit, small beer should be set to work at about 70 degrees; beer intended for keeping, at 56°; and amber or glutinous ales at 54°. When the air is at 50°, all these kinds may be set to work at 50°. In the process of fermentation, the temperature of the wort is often increased as much at 10°; and it may in general be considered, that the wort will be 10° higher at the height of the fermentation, than it was when first put to work, supposing the heat of the air continues the same.

Of yeast. The yeast produced from strong beer is the best to effect a temperate and regular fermentation; that from weak small beer should not be used when the other can be procured; it being apt to act violently for a short time, and then cease. The quantity of the yeast has some effect on the degree of fermentation; a greater quantity will increase the rapidity of the process, in the same manner as a greater degree of heat would, and vice versa; hence a greater proportion of yeast is required in winter than in summer. Small beer intended for immediate use, when the temperature is as low as 40 degrees, will require about eight pints of yeast to one quarter of malt; at 60 degrees six pints; at 70° five pints; and at 80 degrees, only four pints.

All kinds of beer intended for keeping, will require only six pints at 40°, five pints at 60° four pints at 70°, and three pints at 80°.

Of colouring. The colour and flavour of porter and brown beer, was formerly derived from high dried malts, which were scorched and partially charred on the kiln, but this practice being found to cause a great waste of the fermentable matter, which might otherwise be extracted from them, has given place to the more economical plan of colouring beer, obtained from pale malt; the cheapest method of effecting this purpose, is by the addition of burnt sugar, which gives it the desired flavour as well as colour.

The mode of preparing the sugar for colouring, is as follows. One hundred weight of coarse brown sugar is put into a cast iron boiler, of a hemespherical figure, with one gallon of water. This is boiled, and kept constantly stirred, till it turns black, and is of the consistence of treacle; the smoke rising from it is now set on fire, and this communicates to the whole, which is suffered to burn about ten or twelve minutes, and then extinguished by putting on the cover of the boiler. While it is hot, it is diluted with water, to bring it into a liquid state. Three parts of the sugar will make two parts of this colour. When used, it is put into the gyle tun, in the proportion of two or three pounds to a barrel; but this depends upon the colour of the malt from which the liquor is brewed, and the colour which the beer is intended to have.

To avoid the prejudice which the public have generally entertained against the introduction of any matters into the beer, excepting malt and hops, some porter brewers have of late used a portion of their richest wort, instead of sugar, for making the colouring. This is concentrated by boiling it in an iron pan, and is burnt in the same manner as the sugar, over which it has some slight advantage, as the burning the farinaceous matter contained in the wort gives it an agreeable bitter. M. De Roche took out a patent in 1809, for using the husks of the malt for colouring, by burning them to a coffee colour, and mixing them with the malt, at the rate of thirty-one pounds to a quarter of malt; or the water may be coloured before brewing, by infusing these roasted skins in it.

If wort is suffered to remain in the under back too long, a premature fermentation will take place, called by the brewers, foxiness, and the beer produced from such wort, will be nauseous and unpalatable.

A grist of malt is said by brewers, to be set, when instead of separating for extraction, it runs in clods, increases in heat, and coagulates. This accident is owing to the over quantity of heat in the water, applied in the extraction.

The air included in the grist, which is a principal agent in resolving the malt, being thereby expelled, the mass remains inert, and its parts, adhering too closely together, are with difficulty separated. Though an immediate application of more water to the grist is the only remedy, yet as the cohesion is speedy and strong, it seldom takes effect. New malts, which have not lost the heat received from the kiln, are most apt to lead the brewer into this error, and generally in the first part of the process.

OF THE SIGNS WHICH GENERALLY DIRECT THE PROCESSES IN BREWING.

1. When a white flour settles either in the under back or copper back, which is sometimes the case of a first extract, it is a sure sign such an extract has not been made sufficiently hot, or in technical terms, that the liquor has been taken too slack.

2. The first extract should always have some froth, or head, in the under back.

3. The head, or froth, in the under back appearing, red, blue, purple, or fiery, shews the liquors to have been taken too hot.

4. When the grist feels slippery, it generally is a sign, that the liquors have been taken too high.

5. Beer ought always to work kind, out of the cask, when cleansed, but the froth in summer will be somewhat more open than in winter.

6. When the head of yeast in the gyle tun begins to

to sink, it is a sign that the vinous fermentation is ended.

UTENSILS USED IN A BREWHOUSE.

1. *The liquor-back* is a cistern in which the cold water (or as it is called the liquor,) is reserved for use.

2. *The copper*, used for heating the liquor.

3. *The copper back*.

4. *The mash tun* in which the operation of mashing is performed.

5. *The under back*, into which the wort is drawn off after mashing.

6. *The jack-back* which receives the wort after it has been boiled with the hops, and has, in some breweries, a cast iron floor, pierced with small holes, to admit the wort, but retain the hops.

7. *The coolers* are shallow vessels, in which the wort is soon cooled, by presenting a large surface to the air.

8. *The gyle-tuns, or squares* in which the liquor is first put to ferment.

9. *Working tuns*, in which the liquor is cleansed.

10. *Store-vats* are immense tuns used in large breweries, for keeping beer till wanted for sale.

11. *Casks*, large and small.

BRICKLAYING.

Bricklaying is the art of cementing bricks, by lime, or some other cement, so as to form one body.

Bricklayers are, in London, by charter, in 1568, a corporate company, consisting of a master, two wardens, twenty assistants, and seventy-eight on the livery. *For the laws relating to bricklayers, see* BUILDING ACT, *in the second part of this work.*

In London, Bricklaying includes the business of walling, tiling, and paving with bricks or tiles; and it is sometimes united with plaistering. In the country, it is very common for the same person to exercise masonry, bricklaying and plaistering.

Bricklaying is of great antiquity, for we read of it very early in the Mosaic history.

TOOLS USED BY BRICKLAYERS.

1st. *Walling Tools.—The brick trowel*, which is used for taking up and spreading the mortar, in order to cement the bricks together, and for cutting the bricks to any shape required.

2d. *The hammer*, which is used to cut holes in brick walls.

3d. *The plumb rule*, which is generally about 4 feet long, and used with a plumb line, to carry the faces of walls up perpendicularly.

4th. *The level* is from 6 to 12 feet long, and used to try the level of work as it proceeds, more particularly window cills and wall plates.

5th. *The large square*, for trying and setting out the sides of buildings at right angles.

6th. *The rod*, for measuring, is either 5 or 10 feet long, and divided by notches on the edge, into as many feet, the last foot of which is divided into inches.

7th. *The jointing rule*, 8 or 10 feet long, for running the joints of brick work.

8th. *The jointer* is made of steel, and shaped like the letter S; with this and the rule, the joints in brick-work are marked.

9th. *The compasses*. They are used for traversing arches, &c.

10th. *The raker* is a piece of iron, bent like the letter Z. and pointed at both ends; its use is to pick or scrape decayed mortar out of joints in old walls, to be replaced by new.

11th. *The hod*, which consists of two boards put together at right angles, with a handle or leg, somewhat resembling the letter Y, fastened to that part where the two sides meet; one end of the trough is open and the other closed; its use is to carry mortar, bricks, stones, &c. up the ladders, on the shoulder, the handle serving to keep it steady while ascending, and to rest it upon when on the scaffolding. Some sand or dust, is generally strewed over the inner surface, when mortar is carried, to prevent its sticking.

12th. *The line pins*. They are two iron pins for fastening and stretching the line, for the purpose of laying the courses level.

13th. *The rammer*. When ground is of a loose kind,

kind, this tool is used for compressing it, by beating on its surface.

14th. *The iron crow and pick axe* are used for the purpose of breaking through walls; the crow bar is used alone for raising large stones, or any other heavy bodies.

15th. *The grinding stone*, which is used for sharpening any of the tools.

16th. *The banker* is a high bench of 6 to 12 feet long, 2 or 3 feet wide, and 2 feet 8 inches high from the ground, and serves as a bench to rub bricks for arches or other work upon.

17th. *The camber slip*, which is a piece of wood of at least half an inch thick, with one of its edges curved, and rising about one inch in six feet; its use is for drawing the soffit lines of straight arches. If the other edge is curved, it should rise one half as much; this is used for drawing the upper side of straight arches, to allow for their settling. Some workmen prefer the upper side of the arch straight. When the lines are drawn, the camber slip should be given to the carpenter, to enable him to form the centre to the curve of the soffit

18th. *The rubbing stone*, generally of a cylindric form, about 20 inches in diameter, fixed at one end of the banker. When the bricks are brought as near the shape as convenient, by the axe, they are by this rubbed smooth; it is also used for rubbing headers and stretchers, called rubbed returns.

19th. *The bedding stone*, formed of a piece of marble, about 18 inches long, and 8 or 10 inches wide, with one fair side; its use being to try the rubbed sides of the brick, which must be first squared, in order to try whether the surface of the brick is straight, so as to fit upon the leading skew-back, or leading end of the arch.

20th. *The small square*, for trying the bedding of the bricks, and squaring the soffits across the breadth of the bricks.

21st. *The bevel*, for drawing the soffit line on the face of bricks.

22d. *The mould* is used in giving form to the back and face of the brick, that it may have its thickness reduced to its proper taper, to which end, one edge of the mould, (which has a notch for every course of the arch,) is brought close to the bed of the brick already squared.

23d. *The scribe* is any piece of iron ground to a point, to mark by the edge of the rule or mould.

24th. *The tin saw* is for cutting the lines upon the bricks about one eighth of an inch deep, that when the axe is used, the edges may not spalter away. It is also used in cutting the soffit through its breadth, in the direction of the tapering lines, drawn on the face and back of the brick; the cut being made deeper on the face and back than in the middle of its thickness, for the purpose of entering the axe. The saw is also useful in cutting false joints.

25th. *The brick axe* is used for axing off the soffits of bricks to the scribes, and saw cuttings. The more care that is taken in axing the less will be the labour of rubbing.

26th. *The tamplet* is used in taking the length of the stretchers and width of the header.

Note. The last ten articles relate to the cutting of gauged arches.

27th. *The chopping block* is any convenient piece of wood, placed so as to be three inches from the ground, supported either on legs, or piers, and used for axing bricks on. Its length must be according to the number of men that are to work at it.

28th. *The float stone.*—This is used to rub the curved surface of the bricks smooth; it is necessary to bring it as near as possible to the figure of the surface intended to be rubbed before the operation is began.

OF DIFFERENT KINDS OF BRICKS.

Bricks are a kind of artificial stone, made by tempering clay to a proper consistence, and forcing it into a mould, to give it shape, which is that of rectangular prism, 10 inches in length and 3 in breadth; these are dried in the sun and then burnt in stacks or clamps, or in a kiln; in which operation they are reduced to 9 inches long, $4\frac{1}{4}$ broad, and $2\frac{1}{4}$ thick, this, however, varies according to the quality of the clay, and the quantity of burning.

There are several kinds of bricks, as marls, stocks, and place bricks. The principal difference consists in the care in tempering the clay, and diffusing the heat through the whole in burning. The finest kinds of marls are called firsts, and are selected for arches over doors and windows, for which they are rubbed to their proper forms; there are also seconds, which are used for fronting.

The best marls are superior to stock bricks in colour, which is a pale yellow, and consequently more chaste for the front of a house, red being too glaring, particularly for country houses, where it very ill accords with the surrounding scenery.

There are also gray stocks, which are of an inferior kind.

What are left of the clamp after the marls are selected, are called place bricks, packings or sandal bricks; these are of a very inferior quality, not uniformly burnt, and are of a redder colour.

Burrs, or, as they are sometimes called, clinkers, are such as are so much over burnt, as to vitrify and run two or three together. The best red brick, made out of the neighbourhood of London, are used for rubbers. Some very good are made at Hedgerly, near Windsor, and are called Windsor bricks; they are very hard, of a fine red colour, and preferred as fire bricks, for which purpose they are much used. Their thickness is only $1\frac{1}{4}$ inch, but their length and breadth, are the same as the stock brick. All bricks are sold by the thousand, and each brick, according

to Act of Parliament, must measure 8¼ inches long, 4 inches wide, and 2½ inches thick.

There is a kind of brick imported from Holland, called Dutch clinkers, very hard, and of a light yellow colour, used much for paving. They measure six inches long and three broad; the best mode of laying them is herring-bone ways.

Paving Tiles are a long flat kind of brick, used for laying the floor of dairies, cheese-houses, &c. their size is about nine inches long, 4½ broad, and 1½ thick.

The different sorts of tiles for covering houses, are pan tiles, which are 13 inches long, and eight broad, and about half an inch thick; their transverse section somewhat resembles the letter, ∽ being two portions of cylindric surfaces on both sides. The part which is of the greatest radius serves as a channel for conducting the rain, whilst the lesser overlops the edge of the adjoining tile. In the formation of the pan tile, a nob is made to project from the surface of the upper end, which serves to hang it on the lath. Laths for tiling are about three-fourths of an inch thick, and 1½ inch broad, and most commonly made of deal. The other sorts of tiles are plain tiles, hip tiles, and ridge tiles.

FOUNDATIONS.

The first thing to be considered when a building is about to be erected, is the foundation.

If there are cellars or underground kitchens, it is commonly found that they are of sufficient depth to find a good and solid foundation; but where this is not the case, the remedies are to dig deeper, or to drive in large stones with the rammer, or by laying in thick pieces of oak, crossing the direction of the wall, and planks of the same timber, wider than the intended wall, and running in the same direction with it. These last are to be spiked firmly to the cross pieces, to prevent their sliding, the ground having been previously well rammed under them.

The mode of ascertaining if the ground be solid, is by the rammer; if by striking the ground with this tool, it shake, it must be pierced with a borer, such as is used by well diggers; and having found how deep the firm ground is below the surface, you must proceed to remove the loose or soft part, taking care to leave it in the form of steps if it is tapering, that the stones may have a solid bearing, and not be subject to slide, which would be likely to happen, if the ground were dug in the form of an inclined plane.

If the ground prove variable, and be hard and soft at different places, the best way is to turn arches from one hard spot to another. Inverted arches have been used for this purpose with great success, by bringing up the piers, which carry the principal weight of the building, to the intended height and thickness, and then turning reversed arches, (as shewn in *plate* I. *fig*. 10.) from one pier to another. It is clear that by this means the piers cannot sink, without carrying the arches, and consequently the ground on which they stand, with them. This contrivance was recommended by Alberti, and was adopted by Mr. Hook, in building Montague House, and I believe is never omitted, where circumstances of the kind before stated, occur, and where the architect employed has any regard to his own or his employer's interest.

Where the hard ground is only to be found under apertures, build your piers on these places, and turn arches from one to the other. In the construction of the arches, some attention must be paid to the breadth of the insisting pier, whether it will cover the arch or not; for suppose the middle of the piers to rest over the middle of the summit of the arches, then the narrower the piers the more curvature the supporting arch ought to have at the apex. When arches of suspension are used, the intridos ought to be clear, so that the arch may have the full effect; but, as observed before, it will also be requisite here that the ground be uniformly hard on which the piers are erected, for it is better that it should be uniform, though not so hard as might be wished, than to have it unequally so; for in the former case the piers would descend uniformly, and the building remain uninjured; but in the latter, a vertical fracture would take place, and endanger the whole edifice.

WALLS.

The foundation being ready, according to the foregoing directions, the destination, or use of the building, with its magnitude, &c. must be considered, in order to use such materials as are best suited to the end required. Thus, in places much exposed to the weather, the hardest and best bricks must be used, and the soft reserved for in-door work, or places where they are less tried; but in this, regard must also be had, to the importance of the building, and whether it is designed for long duration. In slacking lime, use only as much water as will reduce it to a powder, and only about a bushel of lime at a time, covering it over with sand, in order to prevent the gas, which is the virtue of the lime, from escaping.—(*See Cements, in the second part.*)

This is a better mode than slacking the whole at one time, as there is less surface exposed to the air. Before you use the mortar, it should be beat three or four times over, so as to incorporate the lime and sand, and to reduce all knots or knobs of lime that may have passed the sieve. This very much improves the smoothness of the lime, and by driving in air to its pores, will make the mortar stronger: as little water is to be used in this process as possible. Whenever mortar is suffered to stand any time before used, it should be be beat again, so as to give it tenacity, and prevent labour to the bricklayer. In dry hot summer weather, use your mortar soft, in winter rather stiff.

If you lay your bricks in dry weather, and the work is required to be firm, wet your bricks by dipping them in water, or by causing water to be thrown over them before they are used, and your mortar should be prepared in the best way. Few workmen are sufficiently aware of the advantage of wetting bricks before they are used, but experience has shewn that works in which this practice has been attended to, have been much stronger, than others, where it has been omitted. It is particularly serviceable where work is carried up thin, or in putting in furnaces, grates, &c.

In winter, as soon as frosty and stormy weather set in, cover your wall with straw or boards; the former is better than the latter if well secured, as it protects the top of the wall, in some measure from frost, which to building is very prejudicial, particularly, when it follows much rain; for the rain penetrates to the heart of the wall, and the frost, by converting the water into ice, expands it, and causes the mortar to assume a short and crumbly nature, and altogether destroys its tenacity.

In working up the wall, it will be proper not to work more than four or five feet at a time, for as all walls, immediately after building, shrink, the part which is first brought up will remain stationary, and when the adjoining part is raised to the same height, a shrinking or settling will take place, and separate the former from the latter, causing a crack which will become more and more evident, as the work proceeds. In carrying up any particular part, each side should be sloped off, to receive the bond of the adjoining work on the right and left. Nothing but absolute necessity can justify the work being carried higher, in any particular part, than one scaffold, for, wherever it is done, the workman is certainly answerable for all the evil which may arise from such palpable error.

There are two kinds of bond in brick work, which differ materially from each other, and as the subject is of the highest importance to the bricklayer, we shall lay before our readers some excellent remarks, contained in a pamphlet, written on this subject, by Mr. G. Saunders, who has treated it with a degree of attention which its importance requires.

"Bricks laid lengthways in the direction of the wall are called stretchers, and those laid in an opposite way crossing the direction of the wall, are called eaders.

Old English bond, is a continuation of one kind throughout, in the same course or horizontal layer, and consists of alternate layers of headers and stretchers, (*see Figure* 1, 2, 3, 4, *Plate* 1.) the headers serving to bind the wall together, in a longitudinal direction, or lengthways, the stretchers, to prevent the wall splitting crossways, or in a transverse direction. Of these two evils, the former is by much the worst kind, and is therefore most dreaded by the bricklayer."

Mr. Saunders is of opinion, that old English brick work is the best security against these accidents, as work of this kind, wheresoever it is so much undermined as to cause a fracture, is not subject to either of the above evils, but separates by breaking through the solid brick, just as if the wall were composed of one entire piece.

The brick work of the Romans was of this kind of bond, but the specimens of their work, which remain, are of great thickness, and have three or sometimes more, courses of brick laid at certain intervals of the height, stretchers on stretchers, and headers on headers, opposite the return wall, and sometimes at certain distances in the length, forming piers, that bind the wall together in a transverse direction; the intervals between these piers were filled up, and formed pannels of rubble or reticulated work; consequently great substance with strength was economically obtained.

Flemish bond, (*see Plate* 1, *Figure* 5, 6, 7,) which is the second kind, consists in placing in the same course alternate headers and stretchers, which disposition, according to our author, is decidedly inferior in every thing but in appearance, and even in this, the difference is so trifling, that few common observers would be struck with any great superiority, that the former possesses over the latter. To obtain this, strength is sacrificed, and bricks of two qualities are fabricated for the purpose; a firm brick often rubbed and laid in what the workmen term a putty joint, for the exterior, and an inferior brick for the interior substance of the wall; as these did not correspond in thickness, the exterior and interior surface of the wall, would not be otherwise connected together, than by an outside heading brick that was here and there continued of its whole length; but as the work does not admit of this at all times, from the want of agreement in the exterior and interior courses; these headers can only be introduced where such a correspondence take place, which sometimes may not occur for a considerable space.

Walls of this kind consist of two faces of four inch work, with very little to connect them together, and what is still worse, the interior face often consists of brick, little better than rubbish. Notwithstanding this, the practice of Flemish bond, has continued from the time of William and Mary, when it was introduced, with many other Dutch fashions; and our workmen are so infatuated with this practice, that there is scarcely an instance to be seen of the old English bond.

To the Flemish bond alone must be attributed the frequent splitting of walls into two thicknesses, and various schemes have been, from time to time adopted, for the prevention of this formidable defect. Some have laid laths or slips of hoop iron, occasionally, in the horizontal joints between the two courses; others lay diagonal courses of bricks at certain heights from each other; but the good effect of this

last practice is much doubted, as in the diagonal course, by their not being continued to the outside, the bricks are much mangled where the strength is wanted.

Many other practices are enumerated, to unite complete bond with Flemish facings, but with no better success. In *figure* 5 & 6, the interior bricks are disposed with intention to unite these two particulars, the Flemish facings being only on one side of the wall; but this at least falls far short of the strength, obtained by the English manner. There is another evil attending this disposition of the brick, which is the difficulty of its execution, as the adjustment of the bricks in one course must depend on the course beneath, which must be seen or recollected by the workman; the first is difficult, from the joints of the under course being covered with mortar, to bed the bricks of the succeeding course, and for the workman to carry in his mind, the arrangement of the proceeding course, is more than can reasonably be expected from him, and, unless it be attended to, the joints will be frequently brought to correspond, dividing the wall into several thicknesses, and rendering it subject to separation or splitting.

In the old English bond, the outside of the last course, points out how the next is to be laid, so that the workman cannot easily err.

The outside appearance is all that can be urged in favour of Flemish bond, but even in this, Mr. Saunders is of opinion that were the English manner executed with the same attention and neatness that is bestowed on the Flemish, it would be considered as equally handsome. However this may be, it is surely the duty of all who are concerned in this business, to recommend the adoption of the old English bond, and the following are directions for the execution of it.

1st. Each course to be alternately of headers and stretchers.

2nd. Every brick in the same course must be laid in the same direction; but in no instance is a brick to be placed with its whole length along the side of another, but to be so situated, that the end of one may reach to the middle of the others which lay contiguous to it, except the outside of the stretching course, where three quarter bricks necessarily occur at the ends, to prevent a continued upright joint in the face work.

3rd. A wall which crosses at a right angle with another, will have all the bricks of the same level course in the same parallel direction, which completely bonds the angles. *See Fig.* 1, 2, *and* 3. (*For the measuring of all kinds of brickwork see Mensuration.*)

Description of Plate I.—*Fig.* 1, 2, 3, *and* 4, shew the arrangement of bricks in depths of different thicknesses, so as to form English bond.

Fig. 1, is the bond of a wall of 9 inches. To prevent two upright or vertical joints running over each other, at the end of the first stretcher from the corner, place the return corner stretcher, which is a header, in the face that the stretcher is in below, and occupies half its length; a quarter brick is placed next on its side, forming together $6\frac{3}{4}$ inches, and leave a lap of $2\frac{1}{4}$ inches for the next header, which lies with its middle upon the middle of the header below, and forms a continuation of the bond. The three quarter brick, or brick-bat, is called a closer.

Another way of effecting, this, is by laying a $\frac{3}{4}$bat at the corner of the stretching course, for when the corner header comes to be laid over it, a lap of $2\frac{1}{4}$ inches will be left at the end of the stretchers below for the next header, which when laid, its middle will come over the joint below the stretcher, and in this manner form a bond as before.

Fig. 2. A fourteen inch or brick and half wall. In this the stretching course, upon one side, is so laid that the middle of the breadth of the bricks upon the opposite side, falls alternately upon the middle of the stretchers, and upon the joints between the stretchers.

Fig. 3, a two brick wall. In the heading course, every alternate header is only half a brick thick on both sides, which breaks the joints in the core of wall.

Fig. 4, a two brick and a half wall. The bricks are laid as in *Fig.* 3.

Fig. 5, Flemish bond, for a nine inch wall, where two stretchers lie between two headers, the length of the headers and the breadth of the stretchers, extending the whole thickness of the wall.

Fig. 6. a brick and half Flemish bond, one side being laid as in *Fig.* 4, and the opposite side with a half header opposite to the middle of the stretcher, and the middle of the stretcher opposite the middle of the end of the header.

Fig. 7, Another arrangement of Flemish bond: here the bricks are disposed alike on both sides the wall, the tail of the headers being placed contiguous to each other, so as to form square spaces in the core of the wall for half bricks.

Fig. 8, the corner coin of an upwright wall, English bond.

Fig. 9, the coin of an upright wall, Flemish bond.

Fig. 10, Reversed arches, to prevent the ground giving way or sinking.

Fig. 11, a straight arch, which is usually the height of four courses of brick work; the manner of describing it will be shewn in the following figure.

Fig. 12, to draw the joints of a straight arch, let *A. B.* be the width of the aperture; describe an equilateral triangle *A. B. C.* upon this width; describe a circle round the point *C*, equal to the thickness of the brick. Draw D. E. parallel to A. B. at the distance equal to the height of four courses, and

and produce C. A. and C. B. to *d. e.* lay the straight edge of a rule from *c.* to *d.* and with a pair of compasses, opened to a distance equal to the thickness of a brick, cross the line *d. e.* at F. removing the rule from the points C. and D. Place the straight edge againt the points C. and F. and with the same, extend the points of the compass, cross the line D. E. at G. proceed in this manner until you come to the middle, and as it is usual to have a brick in the centre to key the arch in, if the last distance, which we will suppose to be *h. i.* is not equally divided by the middle point K. of D. E. the process must be repeated till it is found to be so.

Though the middle brick tapers more in the same length than the extreme bricks, it is convenient to draw all the bricks with the same mould, which is a great saving of time, and though this is not correctly true, the difference is so trifling as not to affect the practice. It may, however, be proper to observe, that the real taper of the mould is less than in the middle, but greater than either extreme distance; but even the difference between this is so small, that either may be used, or taking half their difference will come very near the truth. This difference might easily be shewn by a trigonometrical calculation, the middle being an isoceles triangle, of which the base and perpendicular are given, the base being a certain part of the top line. In the triangle upon the sides, you have one angle equal to 60 degrees, and the side D. F. is given, and D C, $=(\text{D. K}^2 + \text{K. C}^2)^{\frac{1}{2}}$ can easily be found, so that in this triangle the two sides and the contained angle are given.

Fig. 13 *and* 14.—Ornamental brick cornices. The first is an imitation of the Grecian doric, and the second a dentil cornice. A variety of pleasing symmetry, may be formed by various dispositions of the bricks, and frequently without cutting, or if cut, chamfering only may be used.

Fig. 15. Semi-circular arch, two bricks high.

Fig. 16, 17 18, *and* 19. Brick piers, of various thicknesses, arranged according to Flemish bond.

Fig. 17. A two and half brick pier.

Fig. 18. A three brick pier, and

Fig. 19. Three and half brick pier.

In each of the foregoing, the arrangement of the first and second courses is shown.

Fig. 21. An elliptic arch, struck from two centres A and B.

Fig. 22. A scheme arch, two bricks high.

Fig. 20. Plan of Mr. Tapper's mode of constructing groins, which is a great improvement on the common four-sided groin. The improvement consists in raising the angle of the groin from an octagonal pier, instead of a square one, which gives more strength, and from the corners being removed, renders it more commodious for turning any kind of goods round it; this renders it particularly advantageous in cellars, &c. This convenience is not the only advantage that this construction admits of, as the angles of the groin are strengthened by carrying the band round the diagonals of equal breadth, which affords better bond to the bricks.

Fig. 23. Earthenware pipes, made and sold at the potteries round London; they are intended to carry water and answer very well in many cases: size and price they are made at is as follows:—

$2\frac{1}{2}$ Inch calibre	9d. per foot run.
3 Ditto	10d. ditto.
$3\frac{1}{2}$ Ditto	1s. ditto.

These three sizes are made in lengths of 2 feet 9 inches.

Fig. 24 and 25, are drains of the common construction, the former one being one brick in thickness, and the latter two.

Fig. 26. The cylindrical or improved drain, which is preferable to the former, being much less subject to choak, and kept clean with a much less quantity of running water. They are sometimes made elliptical, for admitting the cleaner with more ease.

Fig. 27. Channel or gutter of bricks, much used in the lower part of Kent and Sussex; they are frequently substituted for small brick dams, by being inverted one over the other.

Fig. 28, 29, 30, 31, 32. Plans and elevations of the coal-oven, used by bakers; the construction of which being new to many bricklayers, we shall subjoin the observations of Mr. Dearn, upon it, as he seems to have paid it that attention which its importance required. Mr. Dearn's opinion differing from that of Mr. Phillips, in many particulars on this head, we have given the whole dispute in his own words, that our readers may the better be able to judge for themselves.

"An oven may be described as an arched cavity, constructed for the purpose of baking bread, meat, &c.

Baking is a trade of considerable importance in large towns, and the profit of the baker being limited in a great measure by the legislature, his attention has been very naturally directed to the means of increasing his gains, and as the only safe and honourable means by which this could be effected, was by the practice of strict economy, he was led to enquire how the necessary degree of heat, (fuel being a principal item in his expenditure,) was to be obtained at the least possible expence. The increasing price of wood not only rendered this attention to economy the more necessary, but convinced those who reflected at all, that if a cheaper substitute was not speedily discovered, their profit, (already very much diminished,) would ultimately dwindle to nothing. In this dilemma, necessity, (the parent of every useful invention), ever fruitful in expedients, readily suggested to those interested, the application of coal to the purposes of their trade; this by repeated trials was found not only practicable, but subsequent experience

ence has so far established its superiority, on the score of expence, that few are now found so bigotted to old customs and insensible to their interest, as to refuse its adoption. To construct an oven to be heated with coal, it is recommended that the frame and door be about a foot square, like the door of a copper, the bars of the furnace about 18 or 20 inches long, and level with the bottom of the oven; that the flue be 18 inches square, the fire to shoot slanting into the oven at the shoulder, so that the fire may fly immediately to the crown and centre, spreading to the haunch and all round; a register is fixed within a little of the flue, entering the oven, which is stopt when the oven is sufficiently heated. A copper is usually fixed five or six inches over the furnace, warm water being an essential requisite in a bakehouse. But as the manner of constructing these ovens is rendered more intelligible by drawings, I have offered for the instsuction of those who do not understand the proper construction, the figures numbered (28, 29, 30, 31, and 32, on *Plate* 1.)

The above passage is the substance of the instructions contained in *Crosby's Builder's Price-Book* on this subject, at least if I understand it right; but as the description given in that work is not only indefinite and unsatisfactory, but objectionable in more points than one; the drawings given on *Plate* 1, have been made out, in order not only to enable the reader to form a more correct idea of an oven so constructed, than it is in the power of words alone to convey; but in order at the same time to point out to him more clearly the objections I have to the above recommendation. In the first place, it is absolutely necessary that advice, to be of any avail, should be clearly intelligible, leaving neither room for conjecture nor doubt; but, in the instance before us, it is both imperfect and obscure: to one who had never seen an oven of this kind it must be altogether useless as being unintelligible, and to those who have, it would be much better to have said, go and build an oven to be heated with coals. In one place it says, " let the flue be about 18 inches square, for the fire to shoot slanting into the oven at the shoulder. By the word flue is here meant (I conclude from what follows) that part of the contrivance in which the fire is placed, usually called the furnace, the fire hole, the stove, &c. but admitting that this expression is even right, would it not, let me ask, have been as well to have made choice of some other, more generally understood. But without disputing Mr. Phillip's application of the word flue, I shall merely state what I have been taught with respect to the flue and the parts immediately connected with it; I have been led to consider the chimney as consisting of three distinct parts, viz. the opening or mouth, in which the fire is placed, the throat, and the flue or funnel. The flue according to this division of the subject, having the same relation to the opening or fire place, as the wind-pipe has to the mouth in the animal system, intimately connected no doubt, but yet distinct in its operation and situation; but if from their general connection, it were admissible to confound the one with the other, and call the mouth the flue, and the flue the mouth, yet it could hardly hold good in this instance, as the connection is by no means immediate, the heat and smoke traversing the whole extent of the oven, before it escapes by the flue, which is situated in front, immediately over the oven door, this door when shut, cutting off all communication between the two. With respect to the size of such fire-place or flue, (as Mr. P. has it) he recommends it to be about 18 inches square. Now the only argument I shall oppose to this, is, that I have seen a large oven (16 bushels) the fire place of which did not exceed 12 inches either way, and though so small (compared with an opening of 18 inches) was certainly greater than was absolutely necessary for the purpose; the draft into this oven when the blower was up, was amazing, and the baker said he entertained no doubt of being able to produce a sufficient heat to run glass; this is all that I consider necessary to oppose to Mr. P's. recommendation.* How far a still greater reduction of the furnace might be productive of good, I will not pretend to decide, yet I cannot help observing, that if it could be reduced to nine inches in height, there would be a saving of some time and trouble, at least in its erection, as in that case, there would be no cutting into the crown of the oven in this place, which if possible should be avoided, not only as being a work of some difficulty, but as tending to weaken a part, already the most exposed to injury, and requiring more frequent repair than any.

Mr. P's preference in favour of 18 inches is founded on the following reason, " for the fire to shoot slanting into the oven, " this at least is the only reason he assigns for his preference. If this property of making the fire shoot slanting into the oven, is peculiar to the dimensions suggested, then the preference is well grounded, but if it is proved common to all, or peculiar to none, how are we to account for this partiality. In short, the instance I have above related, is alone sufficient to convince me that no advantage can arise from making the fire hole more than 12 inches wide and the same in height, on the contrary I am more inclined to believe that it would be better, on most occasions to make

* Whatever be the size or purpose of the fire place, it is always proper to set the bars 8 or 10 inches in from the door, which will keep a supply of coals warming before they are pushed forward into the fire. The importance of this is known to those who have attended to the effect of every fresh supply of coals to the boilers of steam engines, as it instantly stops the boiling, unless this precaution is attended to. It also prevents, in a great measure, the cold air getting in between the door and frame of the fire-place, which frequently happens from the difficulty of fitting iron doors, to iron frames.

make it less. It should be observed, however, that I am speaking only of ovens, of the size usually adopted by bakers, that is, from 8 to about 16 bushels.

The oven which I have selected as an example, and of which I have given the necessary drawings for the instruction of workmen, (see *Plate* 1.) I feel no hesitation in recommending it for adoption, as it is generally admitted to be the best, and though a difference of opinion may, and does prevail, with regard to some of its dimensions, the principle has hitherto remained unquestioned. The points of difference between myself and Mr. Phillips, I leave to the determination of those who feel themselves interested in the decision. The greatest objection I have to Mr. P's account, is, not that he happens to differ with me in the size of the fire hole, for I am even willing to allow that it is possible he may be right; but because the whole of the passage in question is so ambiguously worded, and so loosely put together, that *I* am persuaded no one can make any thing of *it, who is not* already familiar with the subject; let any one previously unacquainted with the matter, peruse the description alluded to, and then turn to the *Figs*. 28, 29, 30, 31, and 32, on *Plate* 1. and say whether the idea he had formed from the description, is in any degree realized or no. If we pretend to give advice, it should be done in such terms as are likely to be understood by those to whom it is directed, otherwise instead of doing good it is most probable we may do harm. To return,—the kinds of coal made use of for heating of ovens, are chiefly the Staffordshire, Hartleys, and Coupen-Main,* as these coals differ only in name, and not in their properties, the only point for consideration is, which will come cheapest, yet I should observe, that there may be some little difference in the strength, though I have not been able to discover it; this matter may be worth enquiry. If these coals should on sufficient trial be found so nearly alike in strength, that the difference is not deemed worth notice, there will be no difficulty in deciding which is the cheapest. The weight of a chaldron of coals is about 28 cwt. the Hartleys and Coupen-Main are sold by the chaldron, and the Staffordshire by the ton; in general the Staffordshire coal will be found most expensive.

Ovens formed after this example will hold, according to their size, as follows:—

Ft.		Ft. In.		
8 wide and	7	0 deep....	8 bushels of bread.
9 ditto and	7	6 ditto....	10 ditto ditto
10 ditto and	8	6 ditto....	12 ditto ditto

If required to hold less than 8 bushels, or more than 12, reduce or increase the proportions accordingly.

Fig. 28, *Plate* 1. Is the plan of an oven, (to be heated with coal) which, according to the above table, will contain 8 bushels of bread, it being 8 feet wide and 7 deep; the fire hole enters the oven in a direction diagonal with the farthest corner, the sides of the oven are carried nearly straight, and turned as sharp as possible at the haunch and shoulder, this form being supposed better calculated to retain the heat than any other; the flue is immediately over the entrance, as described by the dotted enclosure at *a*, on the plan. Welch lumps or fire bricks are used for the stove or fire hole, and the best, or at least the cheapest place to obtain the latter (in the neighbourhood of London) is at a manufactory of this sort in Princes-street Vauxhall, still carried on I believe by a person of the name of Gregory. In business of this nature it is usual to introduce a considerable quantity of old iron hoops, more especially round and over the oven, in order to keep the work together; this precaution is not only necessary with respect to ovens, but is advisable on all occasions, where great heat is required; it is necessary were it merely to prevent the loss of heat, by a seperation of the work, but when it is considered that the escape of the fire, in this way, may be productive of a still greater evil, in which others may be involved as well as ourselves, the neglect of this precaution becomes unpardonable. A piece of cast iron covers the space before the door of the oven, exactly level with its floor; the opening underneath is applied to no particular use, but is generally made a receptacle for lumber; it is commonly done more with a view to lessen the expence than with any other, yet this notion of economy is ridiculed by some, from a persuasion that a great deal of heat escapes this way, if the place can be applied to no real use, I should think it much better done away with, as there is certainly some reason in the objection urged against it.

Fig. 29, *Elevation*. The mouths of coal ovens are closed with a door of wrought iron, in which is a small circular hole with a valve for the convenience of the baker, and to prevent the cooling of the oven, by a frequent opening of the door. To heat the oven, the door is thrown back, and a blower is applied to the mouth, so contrived, as not only to cover the mouth of the oven, but to enclose also the throat of the chimney, by which contrivance the draft is so much encreased, that the necessary degree of heat is very soon obtained; and if at any time the oven is too hot, (supposing that the fire is out) it will only be necessary to throw open the furnace door and put up the blower for a few minutes, the current of cool air which is thus made to pass through it, soon reduces the heat to the temperature required. In the blower is also an opening of the same kind as that in the door, which is opened and shut at pleasure; the course of the flue is described by the dotted lines at *b*. The lead cistern is fixed about five or six inches over the stove, so that the water may be kept warm, but not boiling, from this

* Wood is frequently made use of instead of coals in ovens of this construction particularly by biscuit bakers.

a pipe is brought down, (as shewn) with a cock in the front. The stove is closed with an iron door, as also the ash-pit hole.

Fig. 30. Is the blower, as before described.

Fig. 31. Is the transverse section from *A B* on the plan, looking towards the opening, the fire hole entering the oven at *c*, the crown is turned, with the bricks on end, and instead of centering, the custom is to fill the whole space with sand, clay, or rubbish, which is well trod down, and fashioned to the shape which it is intended the crown shall be of. When the upper work is finished, the sand is dug out of the mouth of the oven.

Fig. 32. Is the longitudinal section from *C* to *D*. In this, the situation, &c. of the flue is clearly evident, and the sectional line of the blower, when in its is place, described by the dotted line *d*; the space under the oven has been before spoken of.

I shall now close this part of the subject, under the fullest conviction that no person can be at a loss, after the information I have given, to construct an oven of this kind, though he may previously be unacquainted with the business.

There are several contrivances to heat ovens with coal, but as that which I have offered is generally admitted to be the best, I have deemed it unnecessary to describe any other. This observation relates only to ovens of the size used by bakers, as it is the general practice to heat small ovens with coal."

An oven, particularly well adapted to the baking of meat in public bakehouses, is described at the end of the article *Baking*.

BRICKMAKING.

Brick-making, the art of forming and manufacturing bricks.

The earliest mention of bricks is to be found in the historical books of the Old Testament, where we find that Noah's three sons, together with their wives and children, departed from the eastward, and travelled into the land of Shinar. "And they said one to another, go to, let us make brick, and burn them thoroughly; and they had brick for stone, and slime,* had they for mortar." Whether these bricks were really exposed to the action of fire, as the passage before seems to imply, or merely dried in the sun, is a point by no means settled; but according to the testimony of Herodotus, who was upon the spot, the bricks which composed the tower of Babylon, were baked in furnaces. That unburnt bricks were also employed in the earliest buildings, appears certain, from the testimony of some of the oldest historians, and from proofs still existing.

Unburnt bricks were used in Egypt; the making them was one of the tasks imposed on the Israelites during their servitude in that country; but the oldest edifices, which at present remain there, are principally of stone. Pococke, however, describes a piramid built of unburnt bricks, called Cloube-el-Menshieh, (the bricks of Menshieh) which are composed of a black sandy earth intermixed with pebbles and shells, the sediment deposited by the overflowing of the Nile. Unburnt bricks are still in common use in Egypt, and many other parts of the east; they were also used on some occasions by the Greeks and Romans. At what time burnt bricks were first introduced, or in what country, cannot be determined, nor indeed is it of any moment. The Greeks were certainly acquainted with the art of burning bricks, as appears from Vitruvius, who instances several celebrated buildings in which this material was used, both sun-dried and burnt.

This author gives us the following directions for making unburnt bricks. They should not be made of stoney, sandy, or gravelly loam, for such kind of earth renders them heavy; and upon being wetted with rain after being laid in the wall, they swell and dissolve; and the straw which is put in them does not adhere on account of their roughness. The earth of which they are formed should be light chalky white, or red. They should be made in spring or autumn, as being the best time for drying; for the intense

* By slime is meant a bitumen or pitchy substance, with which, according to the accounts of travellers, the country about Babylon abounds.

intense heat of summer parches the outside before the inside is dry; which afterwards drying in the building, causes them to shrink and break. They are best when made two years before they are used, as they cannot be sufficiently dry in less time. If they are used when newly made and moist, the plaister work which is laid on them, remaining firm and stiff, and they shrinking, and consequently not preserving the same height with the incrustation, it is, by such contraction, loosened and seperated. At Utica, therefore, the law allows no bricks to be used before they have lain to dry five years.

No bricks of the form now adopted, are found in ancient structures; those being either square or triangular, and more resembling our paving tiles, than bricks, as well in form as in substance. The triangular brick must have possessed considerable advantages over the present kind, their form being calculated to give the most complete bond, and from their thinness they were likely to be better burnt.

Bricks have several advantages over stone, from their porous texture; they unite better with the cement, are much lighter, and the walls built with them are less subject to be damp.

The earth proper for making bricks, is a clayey loam, neither abounding too much with sand, which renders them brittle, nor with too large a portion of argillaceous matter, which causes them to shrink and crack in drying.

The manufacture of bricks has of late years become an object of revenue, and as such, entitled to some consideration; it is, besides, of the utmost importance to the community, inasmuch as the value and comfort of our dwellings, must depend in a great measure on the quality of the materials with which they are constructed, and bricks form no inconsiderable part of them. The best account we have seen of this art, is given in "Malcolm's Compendium of Modern Husbandry," from which we have made the following extract:—

"*The Moulds*, used in making every sort of brick for building purposes, are ten inches in length, and five in breadth; and the bricks when burned, usually measure nine inches in length, and four and one half in breadth, so that the clamp shrinks about one inch in ten. But the degree of contraction, (as we have before seen) which clay undergoes in being burned, does not absolutely depend upon the purity of the clay; for some clay imbibes more moisture than others; if that which imbibes the most is not exposed a much longer time to the frost to divide and separate its particles, and to the heat of the sun to exhale its moisture, than that which imbibes less and is a shorter time exposed; it follows, that while the one will be reduced one inch, the other may lose two or more. Again, the heat of the kiln or clamps, and the situation of the bricks as to heat, will vary the diminution of the subject to be burnt. It is of consequence therefore, in the making of sound hard bricks, that the clay should be dug two or three years before it is used, in order that it may be pulverized; and the oftener it is turned and incorporated, the better will be the bricks. The earth should have sufficient time to mellow and ferment, which will render it more apt and fit to temper; and this operation of treading and tempering ought to be performed more than doubly what is usual; because the goodness of the bricks wholly depends upon the well-performance of its first preparation, since the the earth in itself, before it is wrought, is generally brittle, full of extraneous matter, which requires to be removed, and as it were without unity or stability; but by adding small quantities of water by degrees to it, and working and incorporating it together, the several parts of it are opened, and by being thus exposed to the atmosphere, a tough gluey substance is formed, which, without such tempering, treading, and beating, could not have been produced.

Bricks thus tempered, become solid, smooth, hard, and durable, and one brick, thus made, takes up nearly as much earth, as a brick and a half, made in the common way, which are light, full of cracks, and spongy, owing to the want of due working and management; to confirm this observation, we shall give the following experiment, made by M. Gallon. He took a certain quantity of the earth, prepared for the making of bricks, he let it remain for seven hours, then caused it to be moistened and beaten, during the space of thirty minutes; the next morning the same operation was repeated, and the earth was beaten for thirty minutes; in the afternoon it was again beaten for fifteen minutes. Thus, this earth had only been worked for an hour and quarter longer than usual, but at three different times. The material had acquired a greater density, by this preparation; for a brick made with this earth, weighed five pounds eleven ounces, while another brick made in the same mould, of the earth that had not received this preparation, weighed only five pounds seven ounces. Then having dried these bricks in the air, during the space of thirteen days, and having burnt them with others, without any particular precautions, they were examined when taken from the kiln, and it was found that the bricks made of the earth, which had been the most worked, still weighed four ounces more than the others, each having lost five ounces by the evaporation of the moisture. But their strength was very different, for, on placing them with the centre, on a sharp edge, and loading the two ends, the bricks formed with the well tempered earth, were broken with a weight at each end, of 65 pounds, or 130 pounds in all, while the others were broken with 35 pounds at each end, or 70 pounds in the whole. A mixture of ashes, which is now uniformly practised about London, and light sandy earth, which is usually practise din the country, facilitates

facilitates the work, and serves also to save coals or the wood in burning them.

The excellency of bricks consists chiefly in the first and last operation; for bricks made of good earth, and well tempered, become solid and ponderous, and therefore, will take up a longer time in drying and burning, than our common bricks seem to require. It is also to be observed, that well drying of bricks, before they are burned, prevents cracking and crumbling in their burning; for when the bricks are too wet, the parts are prevented from adhering together. The best way of ordering the fire, is, to make it gentle at first, and increase it by degrees, as the bricks grow harder.

The common computation is, that every acre of land will yield one million of bricks, in every foot in depth, including ashes which are usually mixed with it. In general our fields are shallow with a bottom of gravel, yet we think they will average nearly five feet, though we believe we have none that will run ten twelve or more feet, as about Kingland; at least such is Mr. Malcolm's information on this subject.

Bricks are made by the thousand, as the most satisfactory mode between master and man, and a handy man could mould in in one day, viz. from five in the morning until eight at night, 5000. To assist him in the preparation of the soil, &c. from the heap (which is usually dug after the season for brickmaking is over and laid up) there is generally a gang consisting of six persons; one man tempers and prepares the soil, which is done with a hoe made long, in the shape of a mattock, a shovel, scoop, a thick plank or board, and a cuckhold; with the hoe he pulls down the soil from the great heap, which is chopped backwards with the shovel, to turn it as often as may be necessary, to mix and thoroughly incorporate the ashes and soil together, because it is to be understood, that at the time the soil is dug out, and made into this heap, a layer of coal ashes is alternately placed between a layer of soil, as often and in such quantities in each layer as the quality of the soil and other circumstances may make necessary. The scoop is used to throw water over this portion that is pulled down with the hoe, in order that it may become, more and more, in a tempering state, more soft and ductile; and with the board he kneads it together, over which a certain quantity of sand is thrown, and it is then covered with pieces of sacking or matting, to keep the sun and air from it. A boy scoops or cuts off a slice, with an instrument or shovel having a short handle, and the blade of it made concave, called a cuckhold; this he brings on his arms to the moulding table, which is placed under a moveable shed, upon which, another boy rolls out a lump somewhat bigger than will fit the mould, the table have been previously strewed with sand. The moulder, after dipping his mould into dry sand, placed at one corner of his table, throws the lump prepared, into the mould, and with a flat smooth stick, about eight inches long, previously dipped in a pan of water, strikes off the surplus soil; he then immediately turns out the brick upon a stand, or board, of the same size with the brick; a boy takes it from thence, and places it on a light barrow, with a lattice-work frame fixed over the frame of the barrow, at about three feet high above the wheel, and reduced to about eighteen inches in height towards the handle, forming an inclined plane. The new made bricks are placed on this lattice frame, and over them, sand is thrown in sufficient quantities to prevent their adhering to each other, as well as to prevent in a certain degree their cracking in drying while on the hacks. A boy wheels the barrow to the hacks, and places them with great regularity and dispatch, one above the other, a little diagonally, in in order to give a free passage to the air. Each hack is made wide enough for two bricks, to be placed edgeways across, with a passage between the heads of each brick; they are usually made eight bricks high; the bottom bricks at the end of each hack are old ones.

In showery weather, wheat or rye straw is carefully laid over the bricks that are drying on these hacks, to keep them as free from wet as possible; for the brickmakers do not here, as in some places more distant from the metropolis, go to the expence of roofed coverings, or long sheds; which from the extent of one of these fields would be impossible.

If the weather is tolerably fine, a few days is sufficient to make them dry enough to be turned, which is done by resetting them more open, and turning them; and six or eight days more are required before they are fit to be put into the clamp, for kilns are not in use in this part of the country. When sufficiently dry, the clampmaker levels the ground, generally at one end of the range of hacks, nearly centrical, making the foundation of the intended clamp, somewhat higher than the surrounding ground; and with place bricks, if they have any, or otherwise, with the driest of those just made, makes a foundation of an oblong form, beginning with the flue, which is nearly a brick wide, and running straight through the clamp. In this flue, dry bavins, coals, and cinders (vulgarly called breese,) are laid and pressed in close, in order that the interstices between wood and coal may be properly filled up. On the sides of the flue, the bricks are placed diagonally about one inch asunder, and between each layer of bricks three or four inches of breese are strewed, and in this manner they build tier upon tier as high as the clamp is meant to be; never omitting between each layer, as well as between each brick, that is placed diagonally, to put a due portion of breese. When they have made the clamp about six feet long, another flue is made similar in every respect to the preceding, to the extent of the size of the intended clamp, provided only that the bricks are

are meant to be burnt off quick, which they will be in about 21 or 30 days, according as the weather may suit. But if there is no immediate hurry for the bricks, the flues are placed about nine feet asunder, and the clamp left to burn off slowly. When fire is set to the clamp, and it burns well, the ash hole, being placed at the west end generally, the mouths are stopped with bricks, and clay laid against them: the outsides of the clamps are plaistered with clay if the weather is at all precarious, or the fire burns furiously: and to the end against which addition is made to the clamp, skreens made of reeds worked into frames about six feet high, and sufficiently wide to be moved about with ease, are placed to keep off the weather, and against any particular side where wet is most prevalent. On the top of the clamp a thick layer of breese is uniformly laid.

This is the mode of manufacturing the common grey stocks for walls and common buildings; but some brickmakers, in order to mix the soil and ashes more regularly, perform it with a machine, called a clay mill, which a horse turns round. This machine consists of a tub or tun fixed to the ground, in which is placed perpendicularly an instrument resembling a worm or screw; the soil being put in at top, is worked down by the rotary motion of the worm, and is forced out at a hole made on the side near the bottom of the tub. A man supplies the tub with fresh soil, properly moistened, while the person who supplies the moulder keeps removing that which is thus prepared, or pressed out.

Washed malms, or more properly marls, are made with still greater attention; a circular walled recess is built about four feet deep, and from three to four feet wide, paved at bottom, and from 10 to 12 feet diameter, having a horse-wheel placed in the center; the ground is raised all round it, and a platform made upon a level with the top of the recess. On this platform the horse walks, a pump is fixed into a well, as near to the platform as may be, to supply the recess with water as often as occasion may require. A barrow made to fit the recess, and thick set with long iron teeth, well loaded, is chained to the traces of the horse, who drags this after him; a man wheels a barrow full of soil previously prepared in a heap the same as for the common stocks, and shoots it regularly round the recess, he then pumps a certain quantity of water, which, by means of troughs or shoots, runs on it. The horse is then set in motion, and the barrow being loaded accordingly, forces its way into the soil, admits the water into it, and by thus tearing and seperating it, mixes the ingredients at the same time that it gives an opportunity for stones and other ponderous substances to subside to the bottom. The man keeps supplying it with fresh soil and water until there is a sufficient body in the recess. On one side, but as near to the recess as possible, the ground is made smooth, and dug out about 18 inches or two feet deep into a hollow square; and the soil now becomes paste, and being thereby sufficiently washed, purified, and fluid, troughs are placed from the recess to this hollow ground, and it is pumped or ladled out with scoops or shovels into the troughs, carefully leaving the sediment at the bottom of the recess to be afterwards thrown out on the sides of it, together with stones, bones, &c. Over this hollow square or pit the fluid soil diffuses itself, where it settles of an equal thickness, and remains until wanted for use; the superfluous water being either evaporated or drained from it, by its being exposed a certain length of time in so thin a body. When they have got a sufficient quantity of washed earth in this pit, another is made alongside of it, and so they proceed until they have got as much thus prepared, as they are likely to want during the season.

The clamps for burning these better sorts of bricks are individually the same with the other, but greater care is taken in not overheating the kiln, and in causing it to burn moderately, as equably and as diffusively at the same time as possible.

In the country, bricks are always burnt in kilns, whereby less waste arises, less fuel is consumed, and the bricks are sooner burnt. The bricks are first set or placed in it, and then the kiln being covered with pieces of bricks, or tiles, the workmen put in some wood, to dry them with a gentle fire; and this they continue till the bricks are pretty dry, which takes up two or three days, which is known by the smoke turning from a darkish colour to a transparent smoke; they then leave off putting in wood, and proceed to make ready for burning, which is performed by putting in brush, furze, spray, heath, brakes, or fern faggots, according to the scarcity or plenty of those articles in the neighbourhood. But before they put in any faggots they dam up the mouth or mouths of the kiln with pieces of bricks, which is called in some places shinlogs, piled upon one another and close it up with wet brick earth.

The shinlog they make so high that there is but just room above to thrust in a faggot; they then proceed to put in more faggots, till the kiln and its arches look white, and the fire appears at the top of the kiln; upon which they slacken the fire for an hour, and let all cool by degrees. This they continue to do alternately, heating and slackening till the bricks be thoroughly burnt, which is usually effected in 48 hours. One of these kilns will burn 20,000 bricks, and is usually 13 feet long, by 10 feet six inches in depth, and the height about 12 feet. The walls are carried up something out of the perpendicular at the top, and inclining towards each other, so that the area at the top is not more than 114 square feet; the thickness of the walls is one foot two inches.

The bricks are set on flat arches, having holes left them something like lattice work.

Goldham observes that bricks will have double the strength if after one burning they be steeped in water, and burnt a fresh.

As every man who has occasion to use bricks, whether on his own estate, or on that of his landlord, cannot but be sensible of the great value of a perfectly dry house; and as it is impossible a house can be dry if bricks are used which are not sufficiently burnt, such as the place bricks before described, he will do well to consider whether it will not be more advantageous to him in the end, to make use of no other than the best hard scurd bricks, be the colour of them what they may, and be the cost what it will. Such bricks are easily known by their sound, and by their striking fire with steel. It will be found that, besides the comfort and firmness of the building, they will be cheaper than place bricks, together with the expence of battening the walls.

In the interior of the county of Surrey, tiles are almost uniformly used for roofs of houses, and in some instances, on barns; but, between Dorking and Horsham, a heavy, but very durable sort of slate stone is used. Nearer London, slates, either Welsh or Westmoreland, prevail. As there are many persons who give the preferance to tiles, it may not be amiss to give the result of a curious experiment on that subject, as related by the bishop of Landaff.

"That sort of slate, other circumstances being the same, is esteemed the best which imbibes the least water; for the imbibed water not only increases the weight of the covering, but in frosty weather, being converted into ice, it swells and shivers the slate. This effect of frost is very sensible in tiled houses, but is scarcely felt in those which are slated; for good slate imbibes but little water, and when tiles are well glazed, they are rendered in some measure, with respect to this point, similar to slate. I took a piece of Westmoreland slate, and a piece of common tile, and weighed each of them carefully; the surface of each was about 30 square inches; both the pieces were immersed in water for about ten minutes, and then taken out and weighed as soon as they had ceased to drip; the tile had imbibed above a seventh part of its weight of water; and the slate had not imbibed a two-hundredth part of its weight; indeed the wetting of the slate was merely superficial. I placed both the wet pieces before the fire; in a quarter of an hour the slate was become quite dry, and of the same weight it had before it was put into the water; but the tile had lost only about twelve grains of water it had imbibed, which was, as near as could be expected, the very same quantity that had been spread over its surface; for it was the quantity which had been imbibed by the slate, the surface of which was equal to that of the tile; the tile was left to dry in a room heated to 60 degrees, and it did not lose all the water it had imbibed in less than six days.

The finest sort of blue slate is sold at Kendal for 3s. 6d. per load, which comes to £1. 15s. per ton, the load weighing two hundred weight.—The coarsest may be had for 2s. 4d. a load, or £1. 3s. 4d. per ton. Thirteen loads of the finest sort will cover 42 square yards of roof, and 18 loads of the coarsest will cover the same space; so that there is half a ton less weight upon 42 square yards of roof when the finest slate is used, than if it was covered with the coarsest kind, and the difference of the expense of the material, is only 3s. 6d. To balance in some measure the advantage arising from the lightness of the finest slate, it must be remarked that it owes its lightness, not so much to any diversity in the component parts of the stone from which it is split, as to the thinness to which the workmen reduce it; and it is not able to resist violent winds so well as that which is heavier.

A common Cambridge tile weighed 37 ounces: they use at a medium 700 tiles for covering 100 square feet, or about two and a half tons of tile to 42 square yards. Hence, without including the weight of what is used in wrapping over, &c. when a building is covered with copper or lead, it will be seen that 42 square yards of building will be covered by,

	Cwt.
Copper	4
Fine Slate	26
Lead	27
Coarser Slate	36
Tiles	54

From the foregoing statement, it is evident that the consequences arising from a covering with tiles are two-fold; the first, that owing to the weight of them, we are obliged to make our plates and rafters of the roofs, so much stouter and heavier than there is any occasion to do for slates, even of the coarser sort; and consequently this increased strength in the timber, must add to the expence of the roof, supposing that the same thickness of wall be sufficient. Secondly, it is proved, that from the porosity of the tile, it imbibes one seventh part of its weight, or above five ounces of water in ten minutes, and that it requires the heat of 60 degrees, which is five degrees above temperate, and six days to make the tile as dry as it was before it was saturated. How much longer the tile may continue wet, during the moist winter months, if it ever dries at all upon the roofs of our houses, is a question we are not prepared to explain. But Mr. Malcolm thinks, that tiles in a damp state, lodging on timber, for at least six months, must injure the timber, and, together with the unburnt, or place bricks in the walls, must produce an almost perpetual moisture, and make a house damp and unhealthy at all seasons.

Before we conclude this article, we shall lay before

fore our readers, an account of Mr. Cartwright's patent bricks, as stated in the specification, dated April 14, 1795.—"The principle of this invention will readily be comprehended, by supposing the two opposite sides of a common brick to have a groove or rabbet down the middle, which groove must be a little more than half the width of the side of the brick in which it is made; there will then be left a shoulder on each side of the groove, each of which shoulders will be nearly equal to one quarter of the width of the side of the brick, or to one half of the groove or rabbet. (*See Plate* 1, *Miscellanies.*) A course of these bricks being laid shoulder to shoulder, (as in *Figure* 5,) they will form an indented line, or nearly equal divisions; the grooves, or rabbets being somewhat wider than the two adjoining shoulders, to allow for mortar, &c. When the next course comes on, the shoulders of the bricks which compose it, will fall into the grooves of the first course; and the shoulders of the first course will fit into the grooves or rabbets of the second; and so on, as is clearly shewn in the plate. This mode of shaping the bricks is to be preferred, as being perfectly simple; the principle, however, will be preserved, in whatever manner they may be made to lock into, or cramp each other, by whatever form of indenture; or whether by one groove, or more. But it must be observed, in whatever manner the variations from the simple form (*Figure* 1.) is made, except by straight lines, the two sides of the brick, &c. must proportionally vary, so that, when they come together in work, they may correspond and fit each other; an example of which is exhibited in *Figure* 2, where *a* and *b* shew the opposite sides of a brick. It may make some small saving in the expence, though perhaps not a prudent one, if the bricks &c. were of such a width as to admit a common brick, or piece of plain stone, between the shoulders of each of these bricks; in that case, the groove must be made proportionally wider. For the purpose of turning the angles, it may be expedient to have bricks or stones, of such size and shape, as to correspond with each wall respectively; this, however, is not absolutely necessary, as the groove in the bricks, &c. of each wall, where they cross, or meet each other, may be levelled, and the bricks wrap over, as in the common mode. For the purpose of breaking the joints in the depth of the walls, bricks will be required of different lengths, though of the same width. Buildings constructed with bricks, of this principle, will require no bond-timber, one universal bond, running through, and connecting the whole building together; the walls of which, can neither crack, nor bulge out, without breaking through the bricks themselves. When these bricks, &c. that is to say, of the simple form, *Figure* 1, are used for the construction of arches, the sides of the grooves and the shoulders, should be the radius of the circle, of which the intended arch is to be a segment. (*See Figure* 3.) Though, if the circle be very large, the difference of the width of the bricks, &c. at top and bottom, will be so trifling, as to make a minute attention to this particular, scarcely, if at all necessary. When these arches are required to be particularly flat, or are applied in such situations as admit not of end walls, as in the construction of bridges, &c. it may be expedient to have the shoulders dove-tailed, to prevent the arch cracking across, or giving way endwise. (*See Figure* 4.) If the bricks are as wide at the bottom as at the top, the manner of putting them together by a dove-tail, is obvious; when not so wide at the bottom, as the top, on one side of the brick, &c. the sides of the shoulders must be parallel, and on the other, the sides of the groove or rabbets must be parallel, so that the two sides of the bricks, &c. which fall together, may correspond. (*See Figure* 4, *b c.*) In forming an arch, the bricks must be coursed across the centre, on which the arch is turned, and a groove side of the bricks must face the workmen. (*See figure* 6.) It may be expedient, though not absolutely necessary, in laying the first two or three courses at least, to begin at the crown, and work downwards each way. In arch-work, the bricks, &c. may be either laid in mortar, or dry, and the interstices afterwards filled, and wedged up, by pouring in lime putty, plaster of Paris, grouting, or any other convenient material, at the discretion of the workman or builder. It is obvious, that arches upon this principle, having no lateral pressure, can neither expand at the foot, nor spring at the crown; consequently they will want no abutments, requiring only perpendicular walls to be let into, or to rest upon; and they will want no superincumbent weight upon the crown to prevent their springing up—a circumstance of great importance, in many instances, in the construction of bridges. Another advantage attending this mode of arching, is, that the centres may be struck immediately; so that the same centre, (which in no case, need be many feet wide, whatever may be the breadth of the arch), may be regularly shifted, as the work proceeds. But the greatest, and most striking advantage attending this invention, is the absolute security it affords, and at a very reasonable rate, against the possibility of fire; for, from the peculiar properties of this arch, requiring no abutments, it may be laid open, or let into common walls, no stronger than what are required for timbers, of which it will preclude the necessity, and save the expence."

The different kinds of bricks made in this country, are principally place-bricks, grey, and red stocks, marle facing bricks, and cutting bricks. The place bricks, and stocks, are used in common walling. The marles are made in the neighbourhood of London, and used in the outside of buildings; these are very beautiful bricks, of a fine yellow colour, hard, and well burnt, and in every respect

respect superior to the stocks. The finest kind of marle and red bricks, are called cutting bricks, they are used in the arches over windows and doors, being rubbed to a centre, and gauged to a height. There is also a fine kind of white bricks, made near Ipswich, which are used for facing, and sometimes brought to London for that purpose. The Windsor or fire-bricks, which are made at Hedgerly, a village near Windsor, are red, and contain a large proportion of sand; these are used for coating furnaces, and lining the ovens of glass houses, where they stand the utmost fury of the fire. Dutch clinkers are also imported, long narrow bricks, of a brimstone colour, very hard, and well burnt: they are frequently warped, and appear almost vitrified by the heat. The use of them is for paving yards and stables. Sir Henry Wotton, mentions the triangular form of brick, from Daniel Barbaro, with commendation; each side of these bricks, being a foot. They were used in the time of the Romans. Although, on some particular occasions, an alteration in the size of bricks, may not only be admissable, but adviseable, yet, in a general sense, any material deviation from the common form, and size, would be improper.

In laying bricks, in the summer season, it is adviseable to dip them into water, until they become saturated; and when the work is left for only one day, the walls should be as carefully covered as in the winter; for at such time the mortar sets too rapidly, and the necessary cohesion is destroyed. This evil is increased by the dust which hangs about bricks, more especially at this time of the year; and this last circumstance should operate as an additional motive for adopting the above expedient. While the injuries to which brick-work is liable, from frost, &c. is known to all; it is singular, that a point of equal, if not superior importance, should be almost wholly overlooked, or at least, generally deemed too inconsiderable to merit any particular attention.

The legislature has often interfered to regulate the manufacture of bricks. By stat. 12, Geo. 1. cap. 35, earth or clay, designed for making bricks for sale, shall be dug and turned at least once between the 1st. of November, and the 1st. of February, and not be made into bricks till after the 1st. of March, and no bricks be made for sale but between the 1st. of March and 29th. of September. But by stat. 10, Geo. 3. cap. 49, earth may be dug for making bricks at any time of the year, provided such earth be turned once before it be made into bricks. And by the former statute, no Spanish is to be mixed with the earth or breese used in the burning of bricks; and all bricks are to be burnt in kilns or distinct clamps, each set by itself.

By stat. Geo. 2, cap. 22, there may be mixed with the brick-earth any quantity of sea-coal ashes, sifted or skreened through a sieve or skreen half an inch wide, and not exceeding 20 loads to the making of 100,000 bricks, each load not exceeding 36 bushels. And breese may be mixed with coal in the burning of bricks in clamps for sale, &c. Stock bricks, and place bricks, may be burnt in one and the same clamp, so that the stock bricks be set in one distinct parcel, and not mixed and surrounded with place bricks.

For the more effectually securing the observation of these laws, it was enacted by 12. Geo. 1. cap. 35. for the better discovery of offenders, that the master and wardens of the company of tylers and bricklayers should have power to search brick-kilns, &c. but they having permitted, and even encouraged divers persons to make bricks contrary to the directions in the said act by 2. Geo. 2. cap. 15, they are divested of that power, and any two, three, or more persons, appointed by the justices of peace, are empowered, within 15 miles of London, to go in the day time into any grounds, sheds or places where any clay or earth shall be digged or digging, for bricks or pan-tiles, or any bricks or pan-tiles shall be making or made for sale, and there to view, search, and inspect the same, &c. Offenders to forfeit 20 shillings for every thousand of unstatutable bricks, and 10 shillings for every thousand of such tiles; one moiety to the use of the prosecutor, the other to the poor of the parish where the offence shall be committed.

By 17. Geo. 3. cap. 42, all bricks made for sale shall when burned, be not less than 8½ inches long, 2½ thick and 4 wide.

By 43. Geo. 3. c. 69(consolidating the excise duties) passed July 4th. 1803, every thousand of bricks made in Great Britain, not exceeding 10 inches long, 3 inches thick, and 5 inches wide, is liable to a duty of 5s. and exceeding the forementioned dimensions to 10s.; and every thousand of bricks made in Great Britain, and smoothed or polished on one or more sides, not exceeding the superficial dimensions of 10 inches long, and 5 inches wide, is subject to a duty of 12s.; and if such bricks exceed those dimensions, to the duty on paving tiles. The said duties are to be paid by the makers. An additional duty of 10d. per thousand was imposed on bricks and tiles, in the ways and means for the year 1805.

BRUSHMAKING.

As there is scarcely an article of more general consumption or universal application than brushes, it seems wonderful, that so little has been done towards rendering them more perfect. We are afraid this is in a great measure owing to a principle, too commonly acted on, of making things cheap. rather than good. Such a notion will ever operate strongly, to prevent that gradual improvement of the subject which can only arise from more liberal and extended views.

The operation of making a brush, is one of the most simple that can be described, as there is scarcely a tool made use of in the business, which is not familiar to every workman. We shall begin with the *Stock*, into which the hair is fixed; this is made of any kind of wood that is dry and well seasoned, and being brought to the intended thickness, by planing, &c. it is next sent to be bored with a quantity of holes, of a proper size to receive the bunches of hair. This is done by means of a small collar and mandrel, with a short bit of the intended size, fixed to it by means of an inside screw, cut in the wood into which the bit is fitted, which corresponds to the screw on the mandrel. Each bit being thus fitted, is easily changed for a larger or smaller one. The lathe is kept in motion by a treadle. The workman then takes the pattern, which is simply a piece of hard, thin, wood, with holes bored through it, at proper and regular distances from each other, and of a size corresponding with the stock of the brush, to which he attaches it by means of a vice, somewhat similar to those made use of by ladies to confine their work to the table. Things thus arranged, the workman stands at right angles with the mandrel, and his breast against the back puppet, and holding the stock in both hands, with the pattern towards him, enters the bit into each hole, one after the other, perforating the stock, which, from the velocity the bit goes with, is done with astonishing dispatch. This prepares the stock for the reception of the hair, which is previously assorted, both as to colour and quality, in the following manner:—Russia hair is imported in bundles, of about 7lb. each, each bundle contains a variety of shades, inserted in locks, as they are taken from the animal; it is the business of the assorter, to select these into heaps, generally four, which are, black, white, and grey, and the very bright, which the workmen distinguish by the name of lilly white, and keep for particular purposes; sometimes, however, the hair is divided into 14 or 15 different kinds. The next operation, is the drawing or combing it, to deprive it of all the short hair, and other impurities, as well as to separate and make it lay more even; for this purpose a steel-toothed comb is fixed to the table, having about 16 or 18 teeth, of 3, or 3½ inches long, and about half an inch asunder. These teeth are fixed to a stock of wood, which is attached to the bench. Through this comb the hair is drawn, by taking small quantities at a time, in the hand, till it is deprived of all the short and small hair. The hair is then knocked up even, into smaller bundles, which are tied round, and the small ends of the hair, which of course are of very unequal lengths, are cut away, by a pair of shears.* In this state it is handed to the workman who is to set the hair in the stock or wood. This part is performed by a man who sits before a bench, on which is fastened a smooth board, inclining a little towards him; on this board he opens the bundles of hair, taking care not to discompose its arrangement. Having taken in the left hand a stock or wood, bored with holes, as before described, he bends the end of a fine brass, or iron wire, wound round a reel, into a loop, and passes it, in this doubled state, through the first hole, from the back to the front of the stock; into this loop he puts a small bunch of hair, taken from the bench, he then draws strongly on the double wire, with the right hand, which causes the hair to double over the wire, before it can follow it into the hole, the wire is then a little twisted, by way of fastening, and the next hole proceeded to in the same manner. The wire is never broken off, or cut, unless by accident, through the whole process, because, after its entrance into the first hole, it, is simply doubled, and passed through, and in drawing it back again, the single wire alone is drawn o . In order to prevent the workmen's hands being injured by the wire, they arm them with leather, in the same manner as shoe-makers.

After each line of holes is filled, the hair is cut to a proper and equal length, by a pair of large shears, held and opened by the fingers and thumb of the right hand

* Whale bone split very fine, so as to resemble bristles, has of late been much used as a subsitute for hair, it is never used alone, but mixed with hair, and answers all common purposes extremely well. This article is sold of various degrees of fineness; the mode of manufacturing it will be given in the 2nd part of this work, under *Whale bone.*

hand, the lower handle resting in a notch on the bench, to enable the workmen to apply more force by bringing the heel of the hand to bear on the upper handle. Through the lower blade are made two holes, one near the point and the other near the heel; those are to fasten a piece of hard wood, of a proper and equal thickness, to the inside of the blade, which, when the shears are used, is brought to bear against the stock, and serves to keep the blade at the intended distance from the stock, to leave the hair of a proper length. When cutting away the hair with the shears, the ends of the hair are brought to bear against a board standing up and fastened to the bench, which causes them to fall in a proper position for future use, these ends are commonly applied to the making of inferior brushes, such as sweeping brushes, hearth brushes, &c.

The brush is now handed to another workman, who lays a thin vineer of wood on the back, which secures the wire and gives the brush a neat and finished appearance. The vineer is applied to the best clothes brushes with glue, but to common shoe or scrubbing brushes, it is only sprigged on with small brads.

When the glue is dry, the brush is brought to the intended form with a stock-shave, or patten-makers knife, and finished with glass, paper, &c.

In all brushes of the kind we have been describing, *i. e*, clothes brushes &c. the tufts of hair are drawn into the hole by doubling them; the process of fixing the tufts of long haired brushes, such, for instance, as sweeping or hearth brushes, is very different; the hair in these last is set into the wood by dipping the ends of small tufts of hair into pitch, (kept warm by a small charcoal fire, over which a vessel containing pitch is kept,) and splicing it round the pitched end with a bit of thread, then driving it, whilst still warm, into the hole, to which it is attached by the tenacity of the pitch. We are of opinion, that a small quantity of tar would very much improve the pitch by rendering it more ductile, particularly for brushes made in the winter, when it must frequently happen that the pitch is so chilled, by coming in contact with the stock, as to prevent any sticking or cohesion between the hair and the wood.

The other class of brushes are such as are made without any holes for the reception of the hair, and may be with propriety called spliced brushes. Of this kind are the painters and glaziers brushes, and the brushes made use of by masons for colouring and washing the walls of houses. The handles of the former are made round and tapering, and the workman, after having selected a sufficient quantity of hair, surrounds the handle and splices it round near the small end, the small end of the stick is then passed through a hole in the bench, and the ends of the hair resting on the bench, with a hammer or mallet the handle is driven on, till the large end is buried a sufficient depth in the hair, or in other words, till the hair projects far enough beyond the large end of the stick.

Masons' brushes are made by laying the hair round the flattened end of the stock or handle, and frapping it tight with a list of leather, which is drawn tight, and small flat headed nails driven through the leather and hair into the wood. After this the ends of the hair are scared evenly away with a little pitch and a hot iron.

Tooth brushes, nail brushes, and brushes for a great variety of other purposes, are manufactured in the manner we have described, the only difference being in the materials of which the stocks are made. Tooth and nail brushes are grooved on the back, for the wire to lie in, which grooves are afterwards filled up with sealing wax, and then polished or scraped to a finish, with files &c.

All the waste hair which is drawn out in combing, is sold to the upholsterers for stuffing chairs &c.

Brushes for limners, which are sometimes called tools, are made of very soft hogs hair, and as they exceed the size of any single quill, they are kept together by splitting or opening quills and wrapping them round the hair, letting as much of the quill project beyond the root of the hair, as is sufficient to form a socket for the reception of the handle, which is planted in its place, as soon as the splice has sufficiently secured the quill to the hair; the splicing is then continued some way up the handle, and attaches the brush strongly to it. To bring it to a point, as well as to soften the hair, it is ground on a stone similar to the cutlers grinding stone; after which the splice is rubbed over with a common kind of sealing wax.

Sable brushes are made with much more care than any other kind, and the operation requires much skill and ingenuity. These are all made in single quills from the minutest size to the largest. The great perfection of brushes of this kind is their coming to a point and readily springing up to their proper shape, after having been bent out of it. The latter quality must chiefly depend on the goodness of the hair, but the former in a great measure on the skill of the workman. Hair of a proper quality being laid before the workman, in much the same manner as before described, but not deprived of its small or taper ends, the workman commences by taking a small quantity of the longest hair, for the center of the brush, which he surrounds with other hair somewhat shorter, and proceeds in this way, applying ten or a dozen hairs at a time, till the brush is of a sufficient size for the intended quill; it is then bound neatly round in two or three places, and the quill being softened by soaking in water, is forced into it from the large to the small end. Camel hair brushes are made in the same way as sable, but from the natural softness and taper of the hair, much less nicety is required; as any quantity, not exceeding

exceeding the size of a quill will readily come to a point. Brushes sold under this name are most commonly made of rabbits hair, which the hatters supply, being unfit for their purpose as they use only the down next the skin.

Bottle brushes are made by twisting hair between a wire rope, the hair standing out at right angles to the twisted wire, when a sufficient quantity of hair is put in for the intended purpose, the handle is formed by continuing the twisted wire to the desired length.

BUTTONMAKING.

Buttons, are articles of dress, serving to fasten clothes tight about the body, and made of silk, mohair, horsehair, thread, metal, &c.

The wrought buttons, in silk, mohair, thread, &c. are chiefly made at Macclesfield, and form the staple commodity of that place. The use of them may be traced back nearly two hundred years; they were formerly curiously wrought with the needle and made a great figure in full trimmed suits. In order to favour this button trade, an act of parliment was passed about a century ago, inflicting a penalty upon the wearer of moulds, covered with cloth of the same garment; and this act, after having fallen into neglect, was again attempted to be enforced with rigour, in 1778, and hired informers were engaged thoughout the Kingdom to put it into execution, an odious, and very uncommercial, mode of enforcing a manufacture, the result of which, was rather to promote the use of metal and horn buttons.

It may not perhaps be improper to remark that persons wearing buttons consisting merely of a mould, covered with cloth, are still liable to penalties, from forty shillings to five pounds per dozen. The importation of Buttons is prohibited on pain of forfeiture, and a penalty of £100 on the importer, and £50 on the seller.

1. *Common buttons* are generally made of mohair; some however are made of silk and others of thread, but the last are of a very inferior sort. In order to make a button of this kind, the mohair must be previously wound on a bobbin, and the mould fixed to a board by means of a bodkin thrust through the middle of it; this being done, the workman wraps the mohair round the mould in three, four, or six columns, according to the button.

2. *Horse-hair buttons.*—The moulds of these are covered with a kind of stuff, composed of silk and hair, the warp being balladine silk, and the short horse hair. This stuff is wove with two selvages, in the same manner, and the same loom as ribbons; it is then cut into square pieces, which are sewn round the moulds. The superfluous hairs, and hubs of silk, are next taken off, and the button rendered glossy, which is done by putting a quantity of buttons into a kind of iron sieve, called by the workmen a singing box; then a little spirit of wine being poured into a kind of shallow iron dish, and set on fire, the singing box, containing the buttons, is shaken briskly over the flame of the spirit, by which means the superfluous hair, hubs of silk, &c. are burnt off, without injuring the buttons. Great care must be taken to keep the buttons in the singing box constantly in motion, for if they are suffered to rest over the flame, they will immediately burn. When all the superfluous matter is burnt off, the buttons are taken out of the singing box, and put with crumbs of bread into a leather bag, about three feet long, and of a conical shape; the mouth, (which is at the small end), being tied, the workman takes an end in each hand, and shakes it briskly with a particular jerk, which cleanses the buttons, and renders them very glossy, and fit for sale.

3. *Gold-twist buttons.*—The moulds of these are first covered in the same manner as the common buttons; they are next covered with a thin plate of gold or silver, and then wrought over in different forms, with purle and gimp; the former is a kind of thread, composed of silk and gold wire, twisted together; and the latter, capillary tubes, of gold or silver, about the tenth of an inch long, joined together, by means of a fine needle, filled with silk, and put through them, in the same manner as beads are strung.

4. *Metal*

4. *Metal buttons.*—Are chiefly manufactured in Birmingham, and form a considerable article of commerce.

Buttons, when first given form to, are called blanks, and are either struck out of a large sheet of metal, with a punch driven by a fly-press, or cast in a pair of flasks, of moderate size, containing 10 or 12 dozen each. In this latter case, the shanks are previously fixed in the sand, exactly in the centre of the impression, formed by each pattern, so as to have their extremities immersed in the melted metal, when poured into the flask, by which means they are firmly fixed in the buttons when cooled. The former process is generally used for gilt, and plated buttons, and the latter for those of white and yellow metal. We shall first give an instance of the former mode of procedure, as used in the manufacture of gilt buttons. The gilding metal is an alloy of copper and zinc, containing a smaller proportion of the latter than ordinary brass, and is made either by fusing together the copper and zinc, or by fusing brass, with the requisite additional proportion of copper. This metal is first rolled into sheets, of the intended thickness of the button, and the blanks are then punched out, as before mentioned. The blanks, when formed, if intended for plain buttons, are usually planished by a single stroke of a plain die, driven by the same engine, the fly-press; when for ornamented buttons, the figure is frequently struck in like manner, by an appropriate die, though there are others which are ornamented by hand. The shanks, which are made with wonderful facility and expedition, by means of a very curious engine, are then temporarily attached to the bottom of each button, by a wire clamp, like a pair of sugar tongs, and a small quantity of solder and rosin applied to each. They are in this state exposed to heat, on an iron plate, containing about a gross, till the solder runs, and the shank becomes fixed to the buttons, after which they are put singly in a lathe, and their edges turned off smoothly. The surface of the metal, which has become, in a small degree, oxydated by the action of the heat in soldering, is next to be cleaned, which in this, as well as in many other instances in the manufacture of metallic articles, is effected by the process of dipping, or pickling; that is, many dozens of them are put into an earthern vessel, pierced full of holes, like a culinder, the whole dipped into a vessel of diluted nitric acid, suffered to drain for a few seconds; again dipped successively into four or five other vessels, of pure water, and then dried.

The next operation is rough burnishing, which is performed by fixing the buttons in a lathe and applying to them a burnisher, made of hard black stone got from Derbyshire, secured in a handle, like the diamond of a glazier, by which means, the minute pores, occasioned by the successive action of the heat and the acid, are closed, and the buttons rendered more perfect. The first step towards the gilding of all the alloy of copper, consists in covering the surface uniformly with a thin stratum of mercury, by which means the amalgam, which is afterwards applied, attaches itself to it much more readily than it would otherwise do. This part of the process is called quicking, and is affected by putting any given quantity of buttons, (perhaps a gross,) into an earthern vessel, with a quantity of mercury, which has been previously saturated with nitric acid; and thus, the buttons and mercury are stirred together with a brush, till the mercury, carried by the affinity of the acid to the copper, adheres to the buttons, whose surfaces become uniformly covered with it. The mercury which hangs in loose drops on the buttons, is then shaken off, by jerking the whole violently in an earthern vessel, full of small holes, called by the workmen, a basket; this operation leaves them with an even, and completely covered surface, giving them the appearance of silver; they are then ready for receiving the amalgam. The amalgam is made by pouring any given quantity of mercury into an iron ladle, the inside of which has been previously guarded, that is, rubbed over with dry whiting, to prevent the gold from adhering to the iron; into this mercury, is thrown the portion of pure gold, intended to cover a given quantity of buttons; these two metals are heated together, till the workman perceives that there is a perfect union between them: when he empties his ladle into a vessel, containing cold water. The amalgam being cold, is put into a piece of shamois leather, and squeezed till no more mercury will pass through. What passes the leather, contains not the smallest portion of gold, what remains, will be about the consistency of butter, so completely united, that every particle of mercury will contain an equal portion of gold. The amalgam should then be put into an earthern vessel, and a small quantity of nitric acid, added thereto, allowing sufficient time for the acid to unite with the mercury. But the buttons and amalgam, are commonly introduced first, and a quantity of diluted nitric acid added to them, so that, for want of a complete union between the mercury and acid first, if there be not a superabundancy of acid, there may not be sufficient to carry all the amalgam to the surface of the buttons.

When the acid has had sufficient time to embrace (as workmen call it) the mercury; the buttons should be introduced, and stirred till the amalgam completely attaches to the whole surface of the buttons.

The quantity of gold used, is about five grains to a gross of buttons, of an inch in diameter.* The next

* The reader, unacquainted with this branch of manufacture, will be surprised to learn, how far a small quantity of gold, incorporated with

next process, is the volatilization of the mercury, by heat, which is called by the workmen drying off. This is performed by first heating the buttons in an iron pan, somewhat like a large frying-pan, till the amalgam, with which they are covered, becomes fluid, and seems disposed to run into drops, on which they are thrown into a large felt cap, made of coarse wool, and goat's hair, called a gilding cap, and stirred about with a brush, to cause the gold to be equally spread over them. They are then again heated, again thrown into the gilding cap, and stirred, and these operations are repeated, till the whole of the mercury is volatilized or dried off. This part of the process, as will readily be conceived, is extremely unwholesome, and has the most terrible effects on the constitutions of the workmen. Mr. Mark Saunders, an eminent button-maker, of Birmingham, has substituted the following apparatus, with success.

A hearth, of the usual height is to be erected; in the middle of which, a fire-place must be made, with an horizontal flue, for the purpose of conducting the smoke backwards, to the chimney. An iron plate is to cover the fire-place, over which must be erected a chamber, of a pyramidal form, the back, and sides of which, may be formed of cast, or sheet iron, or any other suitable material, and the front closed with a glass sash, leaving only sufficient room between the hot plate and sash, for moving the pan backwards and forwards with facility; by this means, the workman is enabled to have a full view of his work, without being exposed to the fumes of the mercury. The mercury when volatilized by the heat, will ascend into the top of the chamber, to which is to be fitted, a tube, bent downwards, inserted into a tub or cask, through the cover, which should be made air tight; in this tub or cask, another tube is to be fixed perpendicularly, but bent down at the top, and terminating in an open cask, into which the tube should descend, at least 18 inches. Both the casks must be partly filled with water, nearly as high as the mouths of the tubes. By this contrivance, the mercury will be condensed in the tubs, and the health of the workmen preserved. The latter cask or tub, Mr. Saunders recommends being placed outside the building.

The last process is burnishing, which finishes, and fits them for carding.

The white metal buttons, which are composed of brass, alloyed with different proportions of tin, after having been cast as before mentioned, are polished, by turning them in a lathe, and applying successively, a piece of buffalo skin glued on wood, charged with powdered grindstone, and oil, rotten stone, and crocus martis. They are then white-boiled, that is, boiled with grain tin, in a solution of crude red tartar, or argol, and lastly, finished with a buff, with finely prepared crocus.

5. *Glass buttons.*—These articles are frequently wholly composed of glass, variously coloured, in imitation of the opal, lapis lazule, and other stones. The glass is kept in fusion, and the button nipped out of it whilst in a plastic state, by a pair of iron moulds, like those used for casting pistol shot, adapted to the intended form of the button; the shank is previously inserted into the mould, so that it may become imbedded in the glass when cold.

6. *Mother of pearl buttons.*—The mode of fixing the shanks to mother of pearl buttons, is by drilling a hole in the back of each button which is undercut, that is larger at the bottom than the top; the shank being driven in with a steady stroke, its extremity extends on striking against the bottom of the hole, and becomes firmly rivetted into the button. To these, fossit-stones are frequently added, which are usually attached with isinglass-glue, steel studs are also often rivetted into buttons of this and various other kinds.

7. *Shell buttons.*—Are those which consist of a back, generally made of bone, without any shank, but corded with catgut, and covered in front with a thin plate of metal struck with a die. The backs are cut out with a brace or stock, the bit of which is a circular saw, similar to the saw made use of in trepanning, and the four holes through which the catgut passes, are drilled by four drills moving parallel to each other, and acting at once. They are then corded by children, who tie the catgut on the inside; the cavity is filled with melted rosin, and the metal shell applied warm. The button is then pressed between two centres in a lathe, which are forced together by a weight acting on a lever, and the edges of the shell turned down during its revolution with a small burnisher.

In the year 1790, a patent was granted to Mr. Henry Clay, of Birmingham, for a new method of manufacturing buttons of slate or slit stone; and in 1800, Mr. Joseph Barnett, of the same place, obtained a patent for a mode of making buttons, by fixing two shanks or other fastenings on one button, one at each side, on the under surface, opposite to each other, instead of only one in the centre,

By 36 Geo, 3, c. 60. any person putting false marks on gilt buttons, erasing any marks except such as express the real quality, or any other words, except real gilt, or plated, incurs the penalty of forfeiting such buttons, and also £5. for any quantity not exceeding 12 dozen; and if above, after the rate of £1. for every 12 dozen. The penalty, however, does not extend to those who mark the words double

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with mercury, will spread over a smooth surface of copper. Five grains, worth one shilling and threepence, on the face of a gross, that is 144 buttons, each of one inch diameter, are sufficient to excuse the manufacturer from the penalty inflicted by an act of Parliament: yet, many, upon an assay, are found to be deficient of this small quantity, and the maker fined, and the buttons forfeited accordingly. Many hundred grosses have been tolerably gilt with half that quantity; to such extent can gold be spread, (when incorporated with mercury,) over the surface of a smooth piece of copper."

ble and treble gilt, provided, in the case of double gilt buttons, gold shall be equally spread upon their upper surface, exclusively of the edges, in the proportion of 10 grains to the surface of a circle 12 inches in diameter, and in that of treble gilt, the gold shall amount to 15 grains in the same proportion. The penalty on making false bills of parcels, expressing any other than the real quality of such buttons, is £20. and that on mixing buttons of different qualities, forfeiture of the same, and £5. for any number between one and 12 dozen, and above this number £1. for every 12 dozen. In order to ascertain what shall be deemed gilt or plated buttons, gilt buttons shall have gold equally spread upon the upper surface in the proportion of five grains to the surface of a circle 12 inches in diameter, and plated buttons shall have the superficies of the upper surface made of a plate of silver fixed upon the copper or a mixture of it with other metals, previously to its being rolled into sheets of fillets. All pecuniary penalties may be recovered by action or suit within three calendar months, in the court of Westminster, and one justice may, by warrant, cause metal buttons liable to forfeiture, to be seized and kept in safe custody, to be produced as evidence upon any action, or cause them to be destroyed. Pecuniary penalties may also be adjudged by two justices in the place where the offender resides or the offence is committed. This act, however does not extend to buttons made of gold, silver, tin, pewter, lead, or mixture of tin and lead, or iron tinned, or of Bath or white metal, or any of these metals inlaid with steel, or buttons plated upon shells.

CABINETMAKING.

The business of a cabinet maker, and that of an upholsterer, are now so generally united together, that, any observations on either of these branches, may, with propriety be comprehended under one general head.

As cabinet making may be considered a superior kind of joinery, so much of its principles, and practice, will be found under that article, as to render it unnecessary to enter fully into the constructive part of the art, in the present article; we shall therefore confine ourselves to such particulars, as are peculiar to this branch, and endeavour to point out, for the direction of the student, the various qualifications necessary, to his excelling in it.

These are numerous, and diffcult to acquire, and seldom, if ever, concentre in any single person. The complete cabinet maker, should add to a correct taste, and sound judgment; a knowledge of drawing, perspective, architecture, and mechanics, besides the other qualifications of a good workman. Although the principles of this art, are equally fixed as those of joinery, (so far as they relate to framing, or putting work together,) yet, from the continual change of fashion, continual modifications of them, become absolutely necessary; in order to meet some new circumstances in the execution of the endless variety of articles, which, the wants, or rather the luxuries of the present state of society require.

The art of cabinet making differs from most other arts, in many particulars. In the first place, the articles made by the cabinet maker, are not only very numerous, but there are not, even from the same shop, two articles of the same description. which do not vary in their form and mode of manufacture. In the second place, many pieces of furniture are daily falling into disuse, whilst others are introduced, which, for a time, are considered as indispensably necessary to our comfort. From these circumstances, it must be obvious how impossible it is to lay down precise instructions, as to the formation of particular articles of furniture, where shape and dimensions are continually varying, and indeed, were it practicable, it would be necessary, for the reason before stated, that cabinet, like female fashions, should be published monthly. Still, however, we may offer some observations that may be useful; for though, in some instances, the figure and form of particular articles, may vary, yet the general principles remain the same.

As a first step, we should recommend to the student, the practice of drawing from any good models, but more particularly from subjects connected with architecture, by which means, he will gradually

gradually become more and more familiar with the beautiful combinations, so eminently conspicuous in the remains of ancient Greece and Rome. This will not only give him a facility of drawing any thing that may be required, but it will tend to enlarge his powers of design, and create juster notions of proportions, which is the very essence of this art. A knowledge of architecture is the more necessary, as the stile of furniture should ever be in unison with the character of the building for which it is designed. An acquaintance with perspective, is no less necessary, than a knowledge of drawing: and without its aid, the design for any article of furniture must be very imperfect; besides, it is sometimes necessary, not only to delineate the particular articles of furniture, but to shew the effect it is likely to produce, when placed in the apartment, for which it is designed. By the aid of perspective, one drawing will exhibit more than one side, from one point of view, and consequently, a better, and more connected idea may be formed, of the general effect. There will be no necessity, either for making many drawings for the same piece of furniture, in order to shew its effect at different points.

As drawing will be noticed under a distinct head, it is unnecessary to enter into the subject here. The same may be said of perspective geometry, and mechanics, which must, of necessity, be seperately considered in a work of this kind. We can only earnestly recommend to those who aspire to the attainment of eminence in this art, to study those rules of proportion which are presented in the works of the ancients.

As it is the fashion of the present day, to resort to a number of contrivances for making one piece of furniture serve many purposes, "a bed by night, a chest of drawers by day," it becomes necessary, on this account, as well as on many others, that the complete cabinet maker should be acquainted with the principles of mechanics; which will not only enable him to calculate, with certainty, the effect of any combination of contrivances he may chuse to introduce, in works of this nature, but will save him mortification, and his customers disappointment, in case of failure, arising either from a want of a due proportion of strength, in places where it is required, or from a redundance where less would have better answered the purpose. In this power of calculation, consists the most striking difference between the man who is acquainted with the principles of his art, and him who is not. In the work of the former, you will ever find, that substance is given to such parts only as require strength, as he well knows, that where any part of an article of furniture is heavier than its use requires, it carries with it the means of its own destruction. To an ignorance of this kind may be ascribed, the frequent failure in the mechanical effect of doors and hinges, arising, we are inclined to believe, from the use of hinges of an improper figure, or less strength than circumstances require.

Though we have specified hinges, we do not by any means confine our observations to them, but consider them as extending to a thousand different things; perhaps there is not a single instance of any piece of furniture being made without some defect of this kind, which might easily be obviated, if the geometrical principles of carpentry were better understood, and the knowledge of mechanics more generally cultivated.

The following miscellaneous observations on various branches of this art, will we trust be found useful to the generality of our readers.

All remarks on the nature and application of different kinds of woods, which do not belong exclusively to this trade, will be found under the articles *tree, timber, and wood*, in the second part of our work.

Veneering, Vaneering, or Fineering, is a kind of marquetry, or inlaying, by which several thin slices or leaves of fine wood, of different kinds, are applied and fastened on a ground of some common wood.

There are two kinds of inlaying, the former of which goes no farther than the making compartiments of different woods; the latter which is not so common, requires much more art, and represents flowers, birds, and the other figures. The first kind is what is properly called veneering; the latter is denominated marquetry.

The wood intended for veneering is first sawed out into slices or leaves, about a line thick; and in order to saw them, the blocks or planks are placed upright in a kind of vice or sawing press. These slices are afterwards cut into slips, and fashioned divers ways, according to the design proposed; after the joints have been carefully adjusted and the pieces brought down to their proper thickness, with several planes adapted for the purpose, they are glued down on a block or ground of dry wood, with good strong English glue. After the pieces have been thus joined and glued, the work, if small, is put into a press; if large is laid on a bench covered with a board, and pressed down with poles, or pieces of wood, the upper end whereof, reaches to the ceiling of the room, and the lower rests on the boards. When the glue is quite dry the veneered work is taken out of the press and finished; first with little planes, and then with divers scrapers, or rasps, which take off dents, roughnesses &c. left by the planes. When sufficiently scraped, the work is polished with the skin of a sea-dog, wax, and a brush and polisher of shave-grass, which is the last operation.

Grounds for veneering on, should be very dry, and formed of such wood as is least liable to fly (split) or warp. The veneer should also be dry and well toothed with the tooth-plane. The utmost attention should also be paid to the bringing the veneer to an equal thickness, (which is done with the tooth-plane)

tooth-plane) before it is laid, otherwise there will be considerably more labour and difficulty in bringing the thick and more stubborn parts, sufficiently into contact with the ground on which the veneer is to be laid.

The wood on which the veneer is to be laid, after being toothed, is to have a coat of glue laid on thin with a brush, this must be suffered to dry before the veneer is applied, and kept warm before the fire. The veneer should be wetted with a sponge on the outside, and the glue laid with a brush on the other, while the whole is kept hot with a quick fire raised by a few shavings. In this state it is put on the piece to be veneered, over the surfaces of which the veneering hammer must be drawn in all directions, so as to drive out the superfluous glue at the edges; and let it be observed as a general rule, in this as in all matters where cements are used for uniting substances together, that the more closely the surface can be brought together (and consequently the less cement used) the firmer will be the work.

In large cirular work the same mode is pursued, except that hand screws, and pieces of heated wood are employed to keep down one end whilst the other is laying. Smaller work is frequently done with a hot caul.

Marquetry, differs from the former in many particulars, and may properly be called painting in wood; as various imitations of nature are produced in this way.

Sometimes coloured glass, marble, tortoise-shell and metals are made use of, either singly or united with wood; but such pieces as are composed of stone or glass, are more commonly called mosaic work.

The art of inlaying is very ancient, and is supposed to have passed from east to the west, among other branches of knowledge, brought to the Romans from Asia. At this early period the process was simple, nor did it arrive at any tolerable degree of perfection, till the 15th. century among the Italians; it seems however to have attained its greatest perfection in the 17th. century among the French.

The finest works of this kind were done in black and white only, which is now called Morescos, till John of Verona, a cotemporary with Raphael, who had a genius for painting, stained his wood with dyes or boiled oils, but he went no farther than the representation of buildings and perspectives, which require no great variety of colours. Those who succeeded him, not only improved on the invention of dyeing the woods, by discovering a secret mode of burning them in without consuming, which served exceedingly well for the shadows; but they enjoyed the advantage of acquiring a number of fine new woods, of naturally bright colours, by the discovery of America. With these assistances the art is now capable of imitating many things with almost as much exactness and fidelity as painting.

The ground whereon the pieces are to be ranged and glued, is ordinarily of oak or fir well dried, and to prevent warping, is composed of several thicknesses glued together, with the grain of one layer intersecting the direction of the other. When the wood required for use has been reduced into leaves or planks of the intended thickness, it is either stained with some colour or made black for shadow, which some effect by putting it into sand, intensely heated over the fire, others by steeping it in lime water and sublimate, and others by immersing it in oil of sulphur. Thus coloured, they are reduced to the contour or shape designed in the following manner; which, as the operation requires much patience and attention, is considered as the most difficult part of marquetry.

The two chief instruments used herein, are the saw and the vice; the latter to hold the materials to be formed, the former to take off from the extremities as occasion may require. The vice is of wood, and has one of its chaps fixed; the other is moveable, and is kept open by a wood spring, similar to the smiths vice, but it differs from it in having no screw, whose office is supplied by means of a cord fastened to a treadle, and acted on by the foot, which thereby draws the chaps together.

The leaves to be formed (for frequently three or four of the same kind are united together) are placed within the chaps of the vice, after the design or pattern has been previously glued to the outermost leaf; the workman then presses his foot on the treadle, and thus holding the several leaves firmly together, runs over or rather follows the outline of the design, with very narrow and thin saws. By thus forming two, three, or four pieces together, the workman not only gains time, but the work itself is better enabled to sustain the efforts of the saw; which, how delicate soever it may be, and how lightly soever the workman may conduct it, would without such a precaution raise splinters to the great injury of the work.

If the work is intended to consist of a single sort of wood, or of tortoise-shell on a tin or copper ground, or *vice versa*, two leaves only are formed one on another, viz, a leaf of metal, and a leaf of wood or shell; this is called sawing in counter parts, for by filling the cavities of one of the leaves with the pieces coming out of another, the metal may serve as a ground to the wood, and the wood to the metal.

The pieces thus formed with the saw, and marked so that their correspondent parts may be readily ascertained, are shadowed in the manner already mentioned; they are then veneered or fastened on the common ground, with the best English glue, pressed together as before described, and finished in the same way, and with the same materials as the common veneering; with this difference, however, that in marquetry, the fine branches, and several of the

the more delicate parts of the figures, are touched up and finished with the graver.

A very beautiful method of producing the resemblance of painting on wood has lately been discovered, which, as it has the happiest effect, (particularly in representations of animals, shells &c.) with less trouble than by any of the preceeding methods, we shall give the best account of the process we have been able to procure.

When a design has been fixed on, procure a piece of seasoned wood of a close grain and light colour, (holly is to be preferred where it can be got of sufficient size) and when the outline of your design has been traced upon it, (which may be done by daubing over paper with some grease or oil mixed with the snuffs of candles, and laying it on the wood with the coloured side towards it,) place your design on it, and trace firmly with a skewer or blunt wire, the outline of the subject intended to be transferred to the wood; then remove the paper and print, and you will find the outline of your subject sufficiently strong on the wood; if necessary it may be gone over with a black lead pencil, in order to give more force to certain parts. When this is accomplished, place the board on an easel with the original design by its side. The tools used for producing the effect are very simple, and are made of small bars of copper or iron, (the former of which is prefered) of about four or five inches long and forged with points of different kinds, some sharp, some flat, and others round, with a spill to fix them in a wooden handle, in much the same way as the tinmans soldering-iron. These irons, when heated to a proper degree, are to be used in the same manner as limners use their painting brushes, by applying them first to produce the strongest shadows, and then using them as they cool for the more delicate, taking care during the operation to adapt the different points so as to produce the desired effect. In this way with a very little experience, such surprising force and truth of delineation may be given to designs, that they may be rendered equal almost to the originals.

We have seen a representation of a tiger and other animals done in this way, which might certainly be mistaken, even by judges, for a painting in oil. In this as in painting the right hand is supported on the maul stick, which is held in the left hand; and it is advisable to have a fire near the work, that the tools may be frequently heated, which will obviate the necessity of having them heavy, a circumstance that cannot be too much avoided. We may fairly expect from the specimens we have seen of this ingenious mode of painting, that the pannels of our cabinets may be made to exhibit performances in this way, that shall rival the most successful attempts of imitative art.

"*Blinds.*—The cheapest kind of blind is that formed of green canvas fixed to two sticks, either of mahogany or wainscot, and hung by a couple of rings, and hooks screwed to the lowermost sash frames.

The frames of the sort most commonly used are composed of mahogany, made so as to fold either in two or in one leaf, with green stuff of the same kind strained into a rabbet in the frame. These blinds are sometimes fixed with slip hinges, so that the frames may occasionally be taken off. When they are made to fold, they have a bolt on the left side, and a turn buckle in the centre of the right to keep them in their place.

The more fashionable blinds are all of wood, painted green, except the frame, which is of mahogany. The blind part is either composed of upright or horizontal narrow laths which are an eighth part of an inch thick, painted a bright green, and move by means of a lever, to any position, for admitting more or less light.

In cutting out laths for venetian blinds, to prevent their warping (which they are disposed to do from their thinness and exposure to the sun) saw them with the hand saw from the edges of a deal, instead of from the centre, which is much more subject to warp. If possible it would be advisable to split them out of clean grown stuff in the same manner as common laths, and to plane them up afterwards.

The blinds most approved of at present are with upright laths, and move by turning a brass knob at the upper side of the frame.

The latest improvement of these is by Mr. Stubbs of Oxford-street, who caps the ends of the laths with brass, so that they are secure from splitting by the wire put in to move them by. At each end of the laths are two of these wires, which by holes communicate with two brass slips let into the top and bottom of the mahogany frame. These brass slips slide past each other in the manner of a parallel ruler; for the laths fixed to the brass, act with them in the same manner as the brass joints to the sides of these sort of rulers.

Rolling blinds, for internal use, are either with spring barrels made of tin, or turn on a plain oak stick of 1¼ inch diameter.

Spring rolling blinds are charged by a worm spring, made of wire, coiled up in a barrel, or cylinder, which draws the blind up close to the cylinder, by the relaxing of the spring, in the same way as the chain is wound round the barrel of a watch, by what is commonly called, its going down. Hence, if the power of this spring be not properly adjusted to the length of the canvas, or in other words, to the height of the window, it is very liable to go wrong, and get spoiled. If a spring be over-charged, it has not sufficient room in the barrel, consequently the wire will twist out of form, and the spring will be obstructed; but if it be not enough charged, then it is incapable of drawing up the canvas to the top. To remedy this defect, the

spring must be taken out of the case, by which it is screwed up to the window, and the charge must be increased by a few more turns round the roller, or barrel, before it is put up again. To obviate the defects of these spring blinds, Mr. Stub's has invented a newly constructed spring, which, though confined to a small barrel, will draw up with ease any length of canvas, to 100 feet, if required. And should a window be uncommonly narrow and high, which, upon the old plan, always proved a matter of embarrassment, his spring effectually answers the purpose.

One peculiar advantage accompanying this new invented spring blind, is its not being subject to the defects of the other kind. These blinds are intended to keep the sun from the room, not merely on account of heat, but to prevent the discharge of colours, and the injury done to elegant furniture, in an apartment where the heat of the sun is suffered to have uninterrupted access.

The plain rolling blinds, without springs, are most in use, being both cheaper, and answering the same end. These have either a wood or a brass pulley at each end, one with a channel to receive a line, and the other without any, to guard the canvas as it rolls up, this is effected by a line passing round in the above channel, fixed to a brass rack, containing a small pulley that receives the line, which, by being tight, draws down, and enables the blind to be drawn up to any height.

White Silesia is to be obtained of any width from 2 feet 3, to 4 feet 6, or wider: a great variety of widths should be kept for making blinds, as it is absolutely necessary to have them exactly the width of the window, in order that the selvages may be retained, as hemming would otherwise render the widths too thick to roll close about the cylinder. There are also Venetian blinds for the same purpose, that draw up by pullies fixed on a lath, 1 inch thick, in the same way as a festoon window curtain.

External sun blinds are also various. Those for shop windows come down over a roller, (fixed within a box or case of wood, which receives the canvas,) and when let fall from the inside, are stayed by iron rods.

There are other blinds now in use, for shop windows, made in light frames strained with canvas, which being hinged to an outer frame, made to receive these, sometimes three or more in number, move all at one time to any convenient angle, so as to exclude the sun. The mode by which they move all at one time, is by a small lath, screwed to each frame, so that when one is moved, the other necessarily follows in a parallel direction, being on the same principle that the parlour blinds, with upright laths, are set in motion: for the screw having play at the head, the frames would fall down of themselves, if they were not kept in their appointed positions by a line fixed to the upper frame, and passing through a pulley at the upper end of the outer frame, which is tied to a hook. These blinds are made to take off when they are not wanted.

There are other external blinds for the first floor windows, which draw up under a cornice fixed to the outside of the head frame of the window. But these being of canvas, are not so proper for outside blinds, as those of the Venetian kind, with brass chains, instead of the usual way of hanging the laths in green tape. Those last mentioned have been introduced by Mr. Stubbs, as before noticed, and bid fair to answer the intended purpose as external window blinds. The venetian part is inclosed under a cornice, when drawn up: and in letting them down they are guided by a frame so that the wind cannot blow them aside."

"*Bolts* among cabinet-makers, are of various dimensions and shapes. Those in most common use, are termed flush brass bolts, from 2 to 30 inches in length and used for book-cases.

There are also bolts of iron with necks, used for dining tables. Some use broad flush brass bolts instead of these. They are set on the inside of the linings of square frames, and shut up into the iron strap hinges by which the loose flaps of such tables are fixed to the bed. To receive the bolt the edge of the strap hinge is filed into a notch, so that when the bolt is shut into it, the strap hinge cannot draw off.

Bolts, amongst joiners, are of five or six different sorts; first, plate bolts and also spring bolts are for fastening doors and windows, There are also round bolts of various sizes for large doors and gates, some with necks and others straight. Some curious brass bolts for double doors, are of a late invention; these have plates set on the edge of the door, extending the whole length, so that by a turn of the knob handle in the centre of the door, the bolts shut up and down at the same time. By turning the contrary way, the bolts are relieved, and both the doors open at once, without further trouble. These are very expensive, and only used in grand apartments, most commonly in doors which divide, or open into two spacious rooms.

To avoid the great expence of these, there are others that act on nearly the same principle, named, spring latch bolts, which are about 13 inches long, with a stout plate." Two of these are required to a pair of doors, one at the top, the other at the bottom: the bolts are shut by a spring in each, which on being pressed against by the right hand door, become locked, by which both doors are secured."

"*Brass work* is a material article in furniture, both for ornament and use, and comprehends a great variety of articles, in locks, hinges, and handles: together with curtain and sideboard rods, mouldings and fret work. In the brass articles adapted for cabinet work, the French far exceed this country, as well in their manner of gilding, stiled or molu. The

The elegance of their furniture is considered to depend chiefly on their superior brass work.

Brass beads, and small lines of brass, are now much used in our English furniture, and look very handsome in black rose, and other dark wood grounds. The lines are made of thin sheet brass, which is cut by guages, made by the cabinetmakers, for that purpose. The brass beads are fixed to the work by sharp points, soldered to the inside of the bead, and driven into the wood to which the beads are fixed."

Cauls, are sometimes formed out of pieces of solid wood in the shape wanted; at other times they are straight pieces of the length and breadth required, bent to the proper form by means of saw carfs. To prevent the caul from sticking to the veneer with the glue, it is generally oiled before it is applied, it is afterwards heated and screwed down to the veneer whilst warm, which drives out the superfluous glue, and causes the veneer to lie close to the ground.

Drawers, are always dovetailed together, but are made variously, in other respects; some have a muntan to divide the bottom into two lengths, so that thinner wainscot may serve, and to prevent the joints from giving way. Slips are sometimes glued on the inside of drawers, and planed to receive the bottom, which is the best method for preventing drawer bottoms from splitting, a circumstance that often occurs when they are confined by a rabbet, and the slip is glued down at the under side.

Small drawers, for secretaries and bureaus, are best made by ploughing a dovetail groove in their sides to receive the bottom; there being objections to the practice of rabbeting them in; as in this way the drawer bottom frequently loosens, and scrapes against the partition in which it runs; but in the dovetail groove, which is formed by a plane, the bottom is secured from falling down, by being kept clear of the partition about the thickness of a shilling.

Pillar and claw Tables.—The claws should be carefully dovetailed into the pillar, as upon the closeness of the fit much of the strength depends. An iron plate in one piece with three or four arms to it, according to the number of claws, may be screwed under the claws, which will give great security to the whole. When these tables are intended to turn up, the block or bed fixed at the head of the pillar, should be as large and thick as convenient, for much of the steadiness of the table depends upon it.

Mouldings.—Cabinetmakers have but few moulding planes, almost the whole of their mouldings being formed with about a dozen pair of hollows and rounds. Since beading has been so much in fashion, planes for the purpose have been introduced. All planes for cabinetmakers have their irons set more upright, than those intended for joiners, as the wood with which the former have to work, is in general very cross grained and hard, and would consequently strip were not the irons set in this way.

Mahogany.—Spanish is very preferable to Honduras, but it is much dearer.—To season it, it is exposed some time to the sun and air, both in the wet and dry, after which it should be stowed in the shade in racks, with slips between each plank, that the air may have freeaccess, which is of the greatest consequence. *See more on this subject in the 2nd. part.*

Hair.—The best picked hair is made of horse or bullocks tails, and should not be mixed with short hair. This is the case however with common hair, and the quality of this article is known by the greater or less quantity of the short kind that is introduced. The long is frequently picked out and dyed, for the purpose of being weaved into chair-seatings.

Rims for tea, sandwich and supper Trays.—These should be glued up in three thicknesses in a caul, with the outer one running parallel with the grain of the wood, the middle one across, and each of the three about the thickness of a veneer. When the outer veneer has been laid on the middle one, whilst straight, it should be bent as soon as dry into the caul, and the cross joint should be made as close as possible; the inside slip should be then fitted in the same manner, and then forced into the caul about a third its width, so much of it should be glued as remains above the rim of the former thicknesses, and as much of the inside of the cross grained slip should be glued as is not covered by the last thickness, which is instantly driven down into its place. The bottoms are then grooved for the reception of the rims, into which they are glued.

Handles to trays, should go through and be fastened with a nut and screw at the bottom; for if fastened only to the rim, they are apt to draw it out, when loaded with any considerable weight.

Upper rails for circular Bason Stands are frequently glued up in three thicknesses, all running the lengthways of the grain. The two inner thicknesses are of deal, and the outside one of mahogany.

Cheese-waggons, are glued up in a caul in two thicknesses, the inner one of which runs the lengthways of the grain, and the outside one across.

Planing.—Particular attention should be paid in planing up wood for cabinet work, to do it very true, and work to the lines afterwards.

Mortises and tenons, to be made well, should fit close but not overtight, which some mistake for strong framing, but this never fails to strain the mortise, which, though not visible at the time, will ultimately prove the destruction of the work. This cannot be too much attended to in chair-making, the strength of which depends entirely on the tenons and mortises. The best way to put together framed work particularly chairs, is by the cramp, as blows with the hammer or mallet frequently produce the worst

worst effects, not only by bruising the timber, but frequently by shivering it at parts very remote from the place where the blow was given. This is often the case in spanish wood.

Chair-making.—To this line the preceeding remarks are applicable, and it is also requisite that the greatest possible attention should be paid to the lines of the tenons and mortises, and the closeness of their fitting on both sides. They should also be of as great length as possible, as nothing contributes more to their strength and steadiness.—No branch of this trade requires a complete knowledge of lines more than that of the chair-maker.

Circular rails for tables, and fronts for drawers, are cut out of deal, from 1½ inch to 3 inches thick, laid one over the other by breaking or intersecting the joints as in brickwork. Care however must be taken that the grain run as long as possible at the ends, for the tenons or dovetails. Some saw-cart a piece of inch deal, and after bending it, glue a piece of canvas on the inside; but this is a bad and weak practice, and is therefore never done by the good workman.

Glue.—Good glue is particularly necessary in cabinetmaking, for as the joints of mouldings, &c. cannot be fastened as in joinery, with brads, &c. the whole combination of the work must depend on the goodness and strength of the glue. It should therefore be procured from houses in London, which make a point of selecting strong glue for the trade; but as this cannot always be depended upon, we shall endeavour to point out the best mode of ascertaining the qualities of glue.

Glue of the best quality, swells most in steeping, but does not dissolve till it is exposed to the fire. When glue is steeped over night, for boiling the next day, and the water is found to be glutinous, and the cakes of course not swelled, these are indications of it being bad glue. Old glue is the best, and its goodness or strength increases by frequent exposure to heat, if it be not burnt, which is very commonly the case, by over fierce fires and hasty boiling. To prevent this, the double glue pot with water in the outside vessel, is now generally made use of. To such as do not understand glue boiling, it may be proper to observe, that the cakes should be broken conveniently small, and soaked in as much spring water as will barely cover the whole, otherwise it is in danger of being too thin, which cannot be so easily remedied as when too thick. After remaining in this state twelve hours, it should then be boiled in a copper vessel, over a gentle fire, until the whole is dissolved; and for the purpose of assisting this operation, it should be constantly stirred about with a wooden spatula spoon, and not quitted till a perfect dissolution takes place, when it should be poured through a sieve in order to seperate it from scum and filth. After this it should be put again into the vessel, and boiled up over a smart fire, when it may be poured into a wooden tray to cool, and considered fit for use.

Back boards, in common drawers, are made plain, of half inch deal, but in good work of inch stuff, and are sometimes framed in two, and sometimes in four pannels. In horse or screen dressing glasses, the back board is framed in four pannels of light clean mahogany, half inch thick, rabbetted for a quarter inch pannel, of soft Honduras, as light as possible, that the whole frame may add as little to the weight of the glass as possible, and only require a small lead weight to balance it. The inner edge of the framing is struck with an ovolo, or quarter round.

The back boards or blind frames of large glasses are made of 1½ inch deal, into four or six pannels, with the back boards ploughed into the framing, in order to save the silvering; and as a farther security it is common to line the frames with thin flannel.

Silvering glasses, for the method of, *see the Second part.*

" *Bevel*, amongst cabinetmakers and joiners, is an instrument used to take any angle with, or to mark a line which is not square. For this purpose the blade is made to move in a long groove, inserted in the stock or handle, and fixed to it by a nut and screw, so that it may be altered to suit any degree of obliquity required. In this respect it differs from a square, which is a fixed instrument at the angle of 90 degrees. A mitre bevel is an instrument fixed to an angle of 45 degrees, or which is the same thing, the diagonal line of any square. This instrument is sometimes termed, a mitre templet, in consequence of its use in cutting mitres.

To find the bevel of chair rails, let the learner plane a piece of thin deal, and if the front rail be 18 inches, and the back 15, let him take half of 3 inches, being the difference, and lay on a square line drawn at one end of the lath; then if the length of the side rail be 16 inches, he will lay it on from the 1½ inch, placed as before mentioned, draw in the 16 inches to the edge of the lath, and cut and plane it to this bevel line. He will finally, from the side thus prepared place the bevel, and move the blade till it agrees with the square line that was first drawn, which will give the correct line for the back and front joints of the proposed side rail. In this manner, by a little practice, the young chair-maker may find out any bevel he wants."

" *Butlers Tray.*—These trays are generally made of mahogany; half inch Honduras will do for the sides, but the bottoms ought always to be made of Spanish, or other hard wood, otherwise the glasses will leave such a print, on soft wood, as cannot easily be erased. Their size runs from about 27 to 30 inches the longest way, by 20 to 22 in width, with one end made nearly open, for the convenience of easy access to the glasses. The sides are about 3½ inches deep, rounded at the top, and scolloped down to the narrow end, or front, (it may be called) in

in the form of an ogee. These sides have handle holes, about 4 inches long, and cut 1¼ inch from the upper edges. There are also dinner trays, knife trays, and comb trays, the first of which is used for carrying dishes and plates to the dining table, their sides are 3½ inches deep, all round, with handle holes in each side, which may be made of good Honduras; but the bottoms should be of Spanish, for the reason before assigned. The length of the largest dinner trays is 32 inches, and their width is 2 feet; full sized tea trays, are nearly of the same dimensions. Knife trays of the best kind have each two partitions, with a brass handle clasping them, and screwing to their sides, which are 3 or 3½ inches deep; their inside length is 14 inches, and their width from 10 to 12 inches. The sides of these trays are now made perpendicular. Comb trays are 6 inches by 8, or 9 long, with bevelled sides, and mitred corners. They are mitred upon a block of wood, and keyed at the corners.

Cane work is now more in practice than it was ever known to be at any former period. About 30 years since, it was quite out of fashion, owing principally to the imperfect manner in which it was executed. But on the revival of japanning furniture, it gradually got again into use, and obtained an able state of improvement, so that at present it is introduced into several pieces of furniture, in which its use was unknown a few years ago, particularly in the ends of beds which are framed in mahogany, and then caned, for the purpose of keeping in the bed clothes. Sometimes also the bottoms of beds are caned, and small borders of it are introduced round the backs of mahogany chairs, which look very neat. Bed steps too, are caned; indeed canes are very properly used in any thing where lightness, elasticity, cleanness, and durability, are desirable.

The manner of caning is various. The commonest kind is of one skain only, called by caners, bead-work, and running open. There are other kinds of two skains, and closer, and firmer. The best work is termed bordering, and is of three skains, some of which are done so very fine and close, that they are less than a sixteenth broad, and in many instances, as fine, comparatively, as some canvas.

The cane used for the best work is imported from Bengal, and of a fine light straw colour which forms a most agreeable contrast to almost every colour it is joined with. The yellower kind is generally as strong and durable, but that which has lost either the light straw, or shining yellow colour, ought to be rejected, as having been damaged by salt water, or some other accident, in its importation.

Carpet.—The Persian and Turkey carpets, are held in most esteem. The Parisian carpets are a tolerable imitation of these; but besides the Persian, Turkey, and Parisian carpets, there are the following sorts, which have their names from the places where they are manufactured; as Brussels—Kidderminster—Wilton—Axminster—Venetian, which is generally striped, and Scotch, which is the most inferior, though in most common use, the other sorts, particularly the Brussels, Wilton, and Axminster being very expensive.

To most of the best kind of carpets, there are suitable borders in narrow widths. The stair carpets are, half a yard, half ell, and three quarters wide.

In cutting out carpets, the upholsterer after having cleared the room of all its furniture, proceeds to line out the border with a chalk line, and mark the mitres correctly in the angles of the room, and round the fire place in particular, as in this part any defects are most observable. He then proceeds to cut the mitres of the carpet border, beginning at the fire place; and endeavouring as correctly as possible, to match the pattern at each mitre; in order to do this, he must sometimes cut more or less of the border to waste. He then takes a length of the body carpet, and tacking it up to the border at one end, resents to the strainer, with which he draws it to the other, where he tacks it again, taking care, as he goes on, to match the pattern, which sometimes varies in the whole length, but for which there is no remedy, except by changing the lengths in such a manner as to bring them tolerably near in matching. If the widths do not correspond in number, it then becomes necessary to draw them in at that side of the room where the defficiency may be least seen; but this must be done in such a way that the contracted widths may match, and that there may be nothing offensive in the appearance of the whole. To prevent misplacing any of the lengths, or parts of the border, the upholsterer should take sealing thread, and tack them together where he thinks it necessary, in which state they are taken to the shop and completed.

If a carpet be cut at home, a plan of the room must be accurately taken on paper, with all the sizes of breaks, door ways, windows, angles &c. which must be transferred to some convenient room at home, by a chalk line and square, and then marking off the border, and proceeding as before described.

In laying down a carpet it is generally customary to begin with the fire place first, and after having tacked and secured this, to strain it here and there, so as to bring it gradually to, till the whole is strained close round the room.

Every person employed in taking the plan of a room for a carpet, ought to be acquainted with plain geometry.

Card tables.—In the manufacture of these, there is frequently much trouble in making them stand true in the upper top; to effect which, various methods have been devised by cabinet makers. Some swell the upper tops, by damping them before they are veneered, supposing that the ground will shrink in due proportion with the veneer, so as to keep all

 straight.

straight. This however, often fails, if the top should happen to imbibe much of the wet, for from being so much thicker than the veneer, it takes longer time to dry, and from the veneer being dried first, and losing its power, the ground work naturally draws the top round on the upper side. On the other hand, if the ground be quite dry, and the wood of a soft nature, and care be not taken to shrink the veneer between hot cauls, previous to its being glued down, the top will most likely dish on the upper side. Particular care also should be taken that the top be not left too long in the cauls, for this will help to draw it hollow. It is most advisable for the workman to take out the top soon, and lay the veneer side of it down on the ground, in order that the under side, from being exposed to the air, may draw the veneered side round. No wood will stand so well for these tops, as hard, straight grained mahogany, well seasoned, and jointed in $3\frac{1}{2}$ inch widths. The workman must avoid using curled veneers, and employ those only which are well dried, that they may agree with the ground work; when well sized with glue, they may be laid with the hammer with as much safety as in a caul, and sometimes more so: because as soon as they are laid in this way, the under side may be turned upwards, and the veneered side may be placed so as to exclude the operation of the air.

Banding, or bordering, in cabinetmaking, is a term applied to pannels or compartments of one sort of wood which are edged, or bordered with that of another.

It sometimes happens, that the contrast of bandings may be too strong for the ground veneer to which the banding is joined; in which case the beauty of the veneer will be partly lost, because the eye will be most attracted by the banding, owing to its excessive contrast of colour to the body of the work. Suppose the ground to be a delicate, pale, and richly figured sattin wood, and that there are joined to it a broad black wood border, and another equally broad of white holly, the experiment would prove, that the fine sattin wood veneer, would lose a considerable part of its beauty by the borders. Some degree of this excessive contrast is admissible with safety when the ground veneer is less delicate, or the wood is faulty; for then, the eye will be so much attracted by the banding, as to disregard the imperfections of the ground wood, and consequently the work will be viewed more favourably. On the other hand, the contrast produced by banding, may be, and frequently is, too weak for the ground veneer, in which case considerable expence proves of no utility. This is always the case when poor tulip wood, or even the best of it, is joined to mahogany, for it turns by the air, nearly to a mahogany colour. To produce an agreeable contrast in cross banding, it will require different shades or bands, to the different qualities of wood of the same species. In light coloured mahogany, of a soft quality, and liable to change, dark strong coloured kingswood will produce and maintain to the end, a proper contrast. If it be dark hard wood, not so subject to change, the use of a fair coloured East or West India sattin wood, will create a pleasing contrast. Dark red and light yellow, will always harmonize, and a small quantity of black, with a red ground, will also appear very agreeable, as will a little black with a yellow ground. With respect to agreeable contrast in banding, it is also necessary to adjust its width in a suitable proportion, to the colour and dimensions of the ground work, for if the colour of the banding be not strongly opposed to the ground veneer, it should be used broader, though it be but a small gronnd. But if the contrast be very striking, the width of the banding ought to be reduced in proportion. In cases however, where there is an extensive ground, such as in loo tables, the cross banding will bear a greater width and strength of contrast.

Feathers.—Those feathers which are brought from Somersetshire, are esteemed the best, and those from Ireland the worst. Eider-down is imported from Denmark, the ducks which supply it being inhabitants of Hudson's bay, Greenland, Iceland, and Norway. Our own islands west of Scotland breed numbers of these birds, which prove a profitable branch of trade to the poor inhabitants. Hudson's bay also furnishes us with good feathers.

Swandown is brought from Dantzic, from whence also we have large quantities of feathers.

Several very imposing arts are practised by brokers and dealers in feathers, which the stranger and fair trader ought to be aware of. The feathers plucked from living birds, are the best and lightest, and are of an elastic nature, so that a bed pressed down with the hand, when filled with good feathers, will rise up to its place again.

The method of curing feathers is to disperse them over the floor of a room, exposed to the sun, and when they are thoroughly dried, to put them in bags, and beat them with long poles, for the purpose of cleansing them from dirt, before they are filled into the tick.

Desks for Compting-houses, are generally made double, with a flap each side, suspended to a square part at the top, where is frequently a double brass rail, supported on a double row of pillars, of the same, to sustain such books on, as are not in immediate use. The insides of these desks are generally fitted up with holes, for papers, and drawers for notes. Sometimes they are made of beech or mahogany, and sometimes of deal painted, having the upper side frequently lined with cloth, which is a bad way, as it harbours sand and dirt. The most advisable method is to use a small qnantity of blotting paper, made into the form of a book, to write on, which at once, answers the purpose of the cloth, and

and supersedes the necessity of sand. The frames of all large desks should be put together with bed screws, for the convenience of removing them from one place to another. The height in front of such desks should be 3 feet 5 or 6 inches, including the frame to the top of the flap, and the depth of the desk without the frame, should be 4½ inches, rising to 9 in the centre.

Tambour, in cabinetmaking, is a kind of flexible partition, which is frequently made use of in the shape of covers to ink stands, or as a kind of curtain to wash basons, and pot cupboards. It is made by gluing on strong canvas, a number of slips or beads of any kind of wood, which, when dry, may be easily bent into a cylindrical form, and when cut to the width of the aperture it is intended to close, is made to slide in a groove at each end. These doors, or rather screens, are opened or closed, by means of a brass or ivory knob, and for purposes where no great strength or security is wanted, answer very well.

Pembroke Table.—The size of such tables is from 3 feet 8 inches, to four feet wide, when open; and from 34 inches to 3 feet long when the flaps are down. The width of the bed should never be less than 21 inches, but in general the size is from 22 to 25 inches, and the height never exceed 2 feet 4 inches, including castors.

Doors.—Although cabinetmakers are not bound by the rules of architectural proportions in framing doors, yet no doors ought to be less than the diagonal of the square of its width, unless there is some absolute cause for departing from this rule. Doors are variously made by cabinetmakers; some are framed together, and have pannels ploughed in: and others are rabbetted in with a bead, mitred round to keep them in. Doors of a small size are glued up in the solid, and sometimes clamped. square, or mitred. In wardrobe doors. great care should be taken to have the stuff dry, as they have a considerable draught in their shrinking, and are apt to warp the frames in a manner not easily susceptible of repair. In order to avoid this, it is advisable to let the pannels stand a quarter of an inch within the frame, and fix them dry in by a bead. Round the inner edge of the door frames, a black line may be permitted to cover the edge of the frame standing before the pannels, which, when polished with the mahogany, looks well. The doors of wardrobes should be left half an eighth of an inch over, on both sides; (as in time they will shrink, so as to require to be hinged further in,) that the astragal may cover, which ought always to be brass in this piece of furniture.

Doors for cabinets and commodes, are according to modern taste, framed with a rabbet left, to which green, or other silk is fixed, after they have been wired by the persons who work it.

In designs for book case doors, it is proper to avoid as much as possible all curved lines, as they are difficult to be glazed. Sometimes complicated figures are introduced, by making the pane of glass extend from one right lined bar to another in the door, and laying a kind of false bar over it, of the intended figure, made of the same moulding, without rabbet.

Hinge, a most useful article in cabinetmaking, of which among many others there are the following varieties.

Hinges for tea canisters are made very thin in the joint, and long enough to extend the length of the canister in one piece. They set on perfectly even with the top, so that there is no joint in the way.

Hinges for pulpit doors, are made very wide to receive the whole projection of the cornice, which always crosses the door, and therefore it becomes necessary to use wide-projecting but-hinges, which screw on the edge of the door, and also to the fixed part, whereby the door is thrown out so as to clear the cornice. These hinges are used for other purposes where there are any mouldings in the way of a door.

Swan neck hinges, are a kind of pin-hinge, used for some camp table tops.

Ell-hinges for shaving and dressing tables, are adopted for strength, for the ell-part returns on the front and back edge of the swinging part and secures the top.—H tumbler hinge, to set on the edges of any kind of turn-over frame, as that of a sofa bed, or turn-over table tops.

Pin-hinges, are to avoid the dissagreeable appearance of the knockle of common but-hinges, on the external part of neatly finished work. These are let into the ends of doors, so as to bring the center of the pin even with the front,(otherwise it will not clear in turning,) and that the projecting strap which has the pin may be behind. It is let into the top and bottom of the carcase, into which the door shuts, and the door end slips into the other strap of the hinge which has not the pin.

Butt-hinges, are so called because they butt or stop against some substance of wood, at the edge of any thing to which they are screwed. There are a great variety of butt-hinges, in the practice of cabinetmaking and joinery. Stop but-hinges, are so named because the door or stop of any piece of work only turns a little out of the perpendicular to the edge or surface on which they are set, if they are pressed further the hinge will break.

Rising but-hinges are such, as turn upon a screw in their joints, and are used in enabling doors when they open to clear a carpet, which otherwise they might rub against.

Slip-off but-hinges are used, in cases where the door or window blind, to which they are screwed, is wanted to be taken off occasionally.

Lap-over but-hinges are applied to the top of any piece of work. that requires to be raised about seven eighths

eighths of an inch above the edge, to which it is screwed, so that another top may fall in between them.

Desk but-hinges, are similar to those of the common sort, except only that they are made twice the breadth in the strap part.

Alkanet.—A species of Anchusa, the root of which is much in use amongst cabinetmakers, for making red oil. The best mode of preparing this, is as follows.—Take a quart of good linseed oil, to which add a quarter of a pound of Alkanet root, as much opened with the hand as possible, that the bark of the root which tinges the oil, may fly off; with this mix about an ounce of dragon's blood, and another of rose pink, finely pounded in a mortar; set the whole within a moderate heat for twelve hours at least, though twenty-four would be better. Then strain it through a flannel into a bottle for use. This staining oil is not properly applicable to every sort of mahogany. The open grained Honduras ought first to be polished with wax and turpentine, to fill up the grain, but in general this wood looks best with wax and turpentine only. If however, it should be closed grained and hard, and want briskness of colour, the staining oil will improve it much. All hard mahogany of a bad colour, should be oiled with it, and should stand unpolished for a time, proportioned to its quality and texture of grain. If the oil be laid on hard wood, which is to be polished off immediately, it is of little use; but if it be permitted to stand for a few days, the oil penetrating the grain, hardens on the surface, and consequently will bear a better polish, and look brighter in colour.

Packing.—This is a concern in the cabinet branch that requires great care, particularly when the article to be packed is a large looking glass. Light japanned chairs for bed rooms, are generally packed in slight skeleton cases, after being papered over. Those that arrange the chairs side to side in the case, put a whole width bottom up each end of the case, to receive the hanging bottom the whole length of the case, which is screwed to the under side of the rails of the chairs. When the first three chairs are fixed, they are put down to their place, and the other three are turned down upont hem, after their place has been marked on the batten, they are taken out again, and screwed to it as before described, with two screws to each side rail. The first three are then fastened to their places, with their legs about an inch clear of the bottom of the case. Stays are then placed crosswise under the long batten, to keep it from working in the middle, and the others are laid down in their place with their legs up, and with the seats to each other, (care however being, necessary that they do not rub or touch each other in any part,) and stays are screwed across as before. Others put the hanging battens across the case; consequently every two chairs require two short battens screwed to the under side of the rail, as in the other method. This last way requires a broad bottom on the sides of the skeleton case, placed so as to correspond with the height of the chair seat, and to receive the short battens crosswise. In this manner of packing, the chairs are placed the other way in the case, that is, with their fronts parellel to the ends of the case, and they are then screwed in, two and two together. By this mode the case rerequires to be more than half a foot longer than by the other, but the latter requires to be broader. When chairs are gilt, or richly finished, for drawing rooms, they require a close case of full half inch deal, and the packing is performed in the manner already described, but with greater care.

Packing cases, for large glasses, should have their sides of deal, from two to three inches thick, and either half lapped or dove-tailed at the corners. The tops and bottoms of such cases should be made of inch deal, with three half width battens of inch stuff, running lengthwise, and well nailed, to keep the top, &c. firm, that the case may not easily warp when the glass is in, and occasion its being broken. It is usual, especially if the glass be conveyed by water, to groove and slip the edges of the boards, and even to pitch the joints afterwards, for the purpose of resisting any dashes of salt water that may occur in the voyage, which would totally ruin the silvering by the slightest access to it. When they are conveyed by land, gluing brown paper over the joints in the inside, will be sufficient, provided the case be otherwise well made. Whether by sea or by land, the case should if possible be kept in an upright position on one of its sides. In packing one of these glasses, it is necessary to place crosswise on the bottom, three half battens, on which the blind frame of the glass may rest, with the precaution however, of leaving brass fasteners screwed to the sides of the blind frame, so as to answer the place of the three battens last mentioned. When the glass is in its place, it is common to cover the plate with some kind of paper, and to put at least a batten to each end over the glass, half the width of a deal, which are screwed to the sides of the case. These last battens, if the depth of the case be properly taken at first, will be level with the edge of the case, and will therefore prove a sure defence to the top, and prevent it from being pressed down in the center so as to endanger the glass. The glass is then inclosed, and the top screwed down, (not nailed) with two inch screw nails, two to each board, the joints of which are pitched and canvassed over.

Festoon window curtains among upholsterers, are those which draw up by pullies, and hang down in folds or festoons. These curtains are still in use in bed rooms, notwithstanding the general introduction of French rod curtains in genteel houses. A festoon window curtain, consists generally of three pulls, but where a window is extensive it has four

or five. According to the number of pulls the window lath must be pullied. Such as have three, are done as follows.—Take 4½ inches for the distance of the pullies off each end of the lath, then find the centre, and put the pullies to one side, next to the draw end, equal to their width, that the lines which pass over them may be directed to the right divisions of the curtains. At the draw end there must be three pullies, placed an inch and half from the end. Towards the centre from these, is a pulley 4½ inches from the end, (measuring from that side of the pulley, through which the line passes,) from which it appears that there will be three pulls, and that two of the lines will be 4½ inches off the end of the curtain, and the other in the centre. If the lath have five pulls, then it will require four pullies more, to be placed in equal divisions on the length of the lath, and for these two additional ones, there must be two corresponding pulls at the draw end, so that it will require five pullies in the width of the lath, to be fixed as before.

Polishing.—Different methods of polishing are of course requisite for different kinds of work, as what is useful in one case, may be injurious in others. In drawers, and pieces of furniture, in which the smell of oil would be unpleasant, bees wax rubbed on with a cork, is used, and to remove the clamminess left by the wax on the surface, brick dust should be shaken through a stocking, on a fine cloth, and well rubbed into the surface.

At other times soft wax, formed whilst warm, by the intermixture of bees wax and turpentine, to which is sometimes added a little red oil if the wood should require it. This is laid on with a cloth, and needs no other cleaning off than that of brisk rubbing with a clean rag.

The most general mode of polishing, adopted by cabinetmakers, is with oil and fine brick dust, the oil may be either plain linseed oil, or oil stained with alkanet root. In polishing hard wood, the oil should remain on the surface for a week, but soft wood may be cleaned off in two or three days. Care however should be taken to keep the oil from skinning over, or drying on the surface, by frequently rubbing it over with the oil rag, moistened with a little additional oil. The brick dust and oil must be applied together, and rubbed in till it thickens, and becomes a kind of putty on the cloth, with which the operation must be continued till the desired effect is produced; but the use of any fresh brick dust must be carefully avoided. It is then cleared off by some bran of wheaten flour.

Chairs are generally polished with the following composition and a brush, and afterwards well rubbed off without any brick dust or bran. Take bees wax and a small quantity of turpentine in a clean earthern pan, and place it over the fire till the wax unites with the turpentine; add to this a little red lead, finely ground on a stone, and as much fine Oxford, or yellow ochre as will bring it to the colour of bright mahogany. When the composition is taken off the fire, add a little copal varnish to it, and turn it into a bason of cold water, and form it into balls for use.

CARPENTRY AND JOINERY.

CARPENTRY is the art of cutting out, framing, and joining large pieces of wood, to be used in building.

Joinery, is also the art of working in wood, or of fitting various pieces of timber together, for the ornamenting of certain parts of edifices, and is called by the French *menuiserie*, "small work."

Both these arts are subservient to architecture, being employed in raising, roofing, flooring, and ornamenting buildings of all kinds. The rules in carpentry are much the same as those of joinery; the only difference is, that carpentry includes the larger and rougher kinds of work, and that part which is most material to the construction and stability of an edifice; while joinery comprehends the interior finishing, and ornamental wood work,

Carpentry and joinery may very properly be considered separately. Under the former head, we shall enumerate the most useful tools made use of by carpenters, and then divide the article into three distinct divisions; the first of which, will treat of the most advantageous modes by which timbers in general may be connected together; the second, will describe and illustrate the several parts of constructive carpentry, such as *centers*, *roofs*, *domes*, *niches*, *&c.*; and conclude with a view of the progress of the art, from Godfrey Richards, to the present time; and the third, will comprise some investigations and observations relative to the strength and stress of timber.

ENUMERATION OF THE MOST USEFUL CARPENTERS TOOLS.

References to Plate 1 *of carpentry.*

Figure 7	represents	The *Axe.*
——— 6	———	The *Adze.*
———24	———	The *Saw.*
———13	———	The *Socket chissel.*
——— 5	———	The *Firmer chissel.*
——— 1	———	The *Auger.*
——— 3	———	The *Gimblet.*
———16	———	The *Guage.*
——— 9	———	The *Square.*
———36	———	The *Compasses.*
———21	———	The *Hammer.*
———22	———	The *Mallet.*
———11	———	The *Hook pin.*
———12	———	The *Crow.*
———18	———	The *Plumb rule.*
———19	———	The *Level.*

Besides these, carpenters make use of *ripping chissels, mauls, ten feet rods, &c. &c. &c.* and sometimes of *planes*.

Before we proceed to the consideration of these three divisions of carpentry, it may not be irrelevent to remark, that we shall suppose the material to be arrived in the carpenters yard, and in the state of whole or squared timber. The operations it undergoes from this period to its final employment in a building, may be classed under two general heads, namely, that which relates to individual pieces, and that which relates to their connexion with others. Under the first head come the operations of the pit saw, by which the whole timber is divided and reduced to the required scantlings, a term that means the dimensions, as to breadth and thickness, without reference to the length.

Planing, which is giving a smooth face or surface to wood, by means of the plane.

Mouldings, of various forms, which are performed with particular planes or chissels.

Rebatting, which is a mode of diminishing the width of a square, or rectangular piece of timber, for a certain depth on one edge, thus, taking off a rectangle of the whole width, and less than the depth of the original piece, a mode much used in door cases, and the frames of casement windows, in which the rebate forms a kind of ledge for the door or casement to stop against, and grooving or plowing, in which a narrow channel is excavated out of the thickness of the timber; the groove is either square, forming an equal section in the whole depth, or wider at bottom than at top, which is called a dove-tail groove. Timber may also be sunk where the piece is formed like a wedge, or rounded; or bevelled in various shapes, a term applied when the section forms a figure without right angles.

We now come to the second, and most important head of the operations by which timbers are connected together. These are generally speaking, by mortise and tenon, the former of which is an excavation, and the latter a projection suited to it, and sometimes by scarfes, wooden pins, nails, spikes, bolts, straps, &c. and by other fastenings of iron.

FIRST DIVISION.

On the most advantageous modes by which timbers in general may be connected together.

The modes by which timbers are connected together, are generally speaking, *perpendicularly*, *obliquely*, *sideways and endways*.

When timbers are joined perpendicularly, the fibres and joint of one piece run perpendicularly to the fibres

fibres, of the other, and the joint may then be termed a transverse or a perpendicular joint.

When timbers are connected obliquely, the fibres of the one piece run in an oblique direction, towards those of the other, and for this reason it is called oblique joining, and the joint termed an oblique joint.

Timbers are joined sideways, when their joints are parallel to the fibres of each piece, and therefore it is termed lateral or longitudinal joining, and the joint is called a lateral or a longitudinal joint.

When timbers are joined endways, their common seam or joint is perpendicular to the fibres of each piece, and the joint is then said to be a butting joint.

With respect to joining timbers perpendicularly, *Figure* 1. *Plate* 2. *of Carpentry*, represents a section of a trimmer and a part of the joist, framed with a simple mortise and tenon in a longitudinal direction. The tenon is usually made in the middle with a plain shoulder.

Figure 3. represents a section of a girder through its mortises, and *Figure* 2 and 4. delineate part of the joist in a longitudinal direction. The best method in order to give strength to the tenons, is to make a rest of a short length under it, with a sloping shoulder above, extending in a line from the extremity of the rest. to the perpendicular of the square shoulder below, at the upper edge of the joist.

Figure 8 *Plate* 6. *of Carpentry*, represents the section of a double floor, with a girder, taken in a transverse direction to the bridging joists.

A shews the section of the girder; DE, DE, the bridging joists; a, a, a, represents also the ends of bridging joists; b, b, b, the ends of ceiling joists, chased, mortised into binding joists, by a method which will be hereafter described.

Figure 9, of the same plate, shews the section of a double floor, taken in a transverse direction to the binding joists. A, A, exhibits sections of the binding joists; DE, part of a bridging joist, MN, ceiling joists; and EF, EF, parts of ceiling joists.

It may be readily seen that the tenons of the binding joists are made in the same manner as described in the preceeding design for a girder and joists.

Figure 5 *Plate* 2, exhibits a method whereby a piece of timber may be framed between two parallel pieces, which are supposed immoveable. In order to make close work, the extremity of the tenon and the bottom of the mortise at one end are made to assume the arc of a circle, with its centre in one edge of the mortise; and the extremity of the tenon and the bottom of the mortise at the other end, in a concentric arc from the same centre. The mortise at this end being much longer than the breadth of the tenon, there will be a large part of the mortise still open, which may be afterwards filled up. Instead of the bottom of the mortise, in this instance being formed in the arc of a circle, it may be cut parallel to the edge at the deepest part, as it will not impede the transverse piece going in to its place. In forming the mortise and tenon, at the end where the centre is placed, there is no necessity for the mortise and tenon to form an entire quadrant; but the bottom may be parallel, and the edge only which is opposite the centre made circular. This useful mode of framing is much used in ceiling, joisting for double floors &c. and the long mortises cut in this manner are called chase mortises.

If it be required to notch one piece of timber to another, or to connect the two, so as they may form one right angle, with an equal degree of strength in each. Then each piece should be notched half through, and afterwards the two should be nailed or pinned together. *Figure* 9. represents two pieces of timber framed after this manner, and *Figure* 10 shews the socket of one piece, which receives the neck or substance of the other.

By making a corresponding notch at any convenient distance from the end in each piece; two pieces may be connected together so as to form four right angles; *Figure* 11. shews two pieces framed as above, and *Figure* 12, exhibits the socket of one of the pieces, which is cut out to receive the part remaining in the other, after its socket is also cut out. By this mode of joining timbers, the pieces may be so notched, as to have their surfaces in the same plane, or one above the other, as may be found convenient.

These methods are used to connect bond timbers at the corner of a building. *Figure* 7, represents an excellent mode of fixing beams to wall plates, when the walls are effected by lateral pressure. A small notch is cut out of the beam, and the contrary parts forming a double notch, are cut in the wall plate to receive it. *Figure* 7 represents a longitudinal part of the beam upon a transverse section of the wall plate; and *Figure* 8, shews the upper part of the wall plate wherein the two notches are made.

Figures 13, 14, 15, 16, 17 and 18, represent methods of joining one piece of timber to another, by dovetailing, so that the surface of the one be parallel and perpendicular to that of the other; these figures also represent various forms of cutting the dovetail, and are very useful in shewing the mode of fixing angle-ties to wall plates &c. &c. It is evident that timbers can be joined by this method either perpendiculary or obliquely.

Figure 21, exhibits another method of fixing beams to wall plates, in order to bind the sides of the building together; and *Figure* 22, shews a transverse section at the neck of the dovetail. This method of fixing beams to wall plates is called cogging or cocking.

A piece of timber may be joined at right angles to another in the manner of *Figure* 1, *Plate* 3, which is

is a longitudinal section in the direction of the fibres of both pieces. A mortise is made in the one piece to correspond with its breadth, which is to form the perpendicular, the edge of the tenon is then cut with a dovetail notch, so that the piece may be at right angles with the other, and a wedge or key is next driven from the other edge of the tenon, which forces it quite close. When the timber of which the piece containing the dovetail may be formed is not quite dry, the tenon will shrink in proportion to its breadth, by which circumstance the perpendicular piece will beome liable to be drawn out from the other to a certain degree. This defect is remedied in the section exhibited at *Figure* 19, *Plate* 2, where instead of the edge of the tenon being cut in the form of a dovetail, a notch is made in it. *Figure* 20, shews another view of the perpendicular piece with the wedge.

Another mode of fixing one piece perpendicular to another is by fox-tail wedging, and is executed by making in the piece forming the base, a mortise nearly equal in depth to the piece; by enlarging its edges towards the bottom, and by cutting the tenon of the perpendicular piece so as to fit the upper part of the mortise. Two wedges are then fixed to the bottom of the tenon; and when the perpendicular piece is driven, the wedges being resisted by the bottom, will split the ends of the tenon, and fill up the mortise to the breadth at the widest place. In order to enlarge the tenon in breadth still more towards its extremity, two other smaller wedges may be put in, the ends of which must not reach quite so far as those of the other two. When the larger wedges are partly driven, the small ones will then begin to widen the end of the tenon likewise, and make it fill the mortise entirely at the bottom. By this method, as long as the wedges are kept from slipping, one piece can never be drawn from the other, without breaking the tenon.

Figure 23, shews the edge of the piece on which the mortise is cut.

Figure 25, exhibits a section of it through the mortise; and *Figure* 24, represents a section of the perpendicular piece with the wedges.

Figure 2, *Plate* 3, shews a transverse section of a post, with two beams longitudinally bolted to it, in the same manner as cogging of beams to wall plates is performed.

Figure 3, is a part of one of the beams, with notches made in it to receive the post; and *Figure* 4, is a part of the post exhibiting the notches made in it to receive the beams.

Figure 1, *Plate* 4, is an elevation of the bottom of a king post, fixed to a tie beam, by a bolt; and *Figure* 2, is a vertical section cutting the beam transversely; two nuts are used on this occasion in order to give greater security; one of which is let in from the face of the beam, and the other from the edge. Another method of strapping a tie beam to a king post is shewn at *Figure* 3.

The mortise of the strap on both sides is made oblong, and for the purpose of giving the necessary draught to the wedges, the mortise through the king post is made somewhat lower.

Figure 4, is a longitudinal section of the king post, with a transverse section of the beam. The upper part of this figure shews the manner of fixing the wedges, with the form of the washers, which are necessary, in order to prevent the strap on each side from penetrating into the wood, the whole force of the friction being taken away by these means from the straps.

With respect to joining timbers obliquely, the diagram delineated at *Figure* 6, *Plate* 2, represents the mode of framing a transverse joist between two parallel ones, the vertical surfaces of which are oblique to each other. The upper edge of the transverse piece is placed downwards upon the top of the parallel joists and marked at the interval or clear at each end; it is then turned upwards into the position in which it is intended to be placed, the mark at one end is brought into a right line with the side of the joist, and a line is then drawn by the side of a straight edge, placed against the side of the joist, and the plane of the transverse piece. The line at the other end is drawn in the same manner. This mode of framing is called by workmen, tumbling in joists.

Figures 5, 6, 7, *in Plate* 4, exhibit the methods used for the meeting of a brace and straining piece under a truss beam, of these methods the first is the best.

Figure 8, exhibits a method of securing a collar beam at one extremity, and preventing it from being pulled away at the joint; by a bolt made to pass through the rafter, at the angle formed by their meeting.

Figure 9, represents one form of the heel of a principal rafter, with the socket cut in the end of the tie beam to receive it; this method however, is defective in strength, because the small part cut across the fibres of the beam being too near its extremity, it will become liable to be forced away in consequence of its having to sustain the entire force of the rafter. *Figure* 10, is intended to remedy this defect, by forming two abutments equally deep into the beam; a mode, which not only produces a resistance to the rafter, fully equal to that in the former method, but adds to it the strength of the intermediate part contained between the two abutments. The intermediate part in this mode from having the fibres cut across, is easily split away.

Another mode of forming a double resistance, is shewn at *Figure* 11. In this figure it will be observed, that the heels of the rafter and the socket, are cut parallel to the fibres of the tie beam, the end of the rafter forming one abutment, and the tenon the other, which has the effect of removing it farther from the extremity.

Figure 12 represents the best mode of forming a

a resistance on the heel of the rafter and socket at the extremity of the beam. The abutment by this plan, is brought nearer to the inner part of the heel, which of course leaves a greater length on the end of the beam, and renders the resistance still greater, than that produced by the wood. In order still further to strengthen and secure it, a strap may be placed round the extremity of the rafter, and the two ends may be bolted together, through the beam, as is represented in *Figures* 12 and 13.

Figure 14 represents the mode of forming a junction of the rafters, and the joggle head of the king post, together with the manner of strapping them. This mode, however, will be found defective when the joggle head of the king post should happen to shrink; for it is evident, that in that case, the roof will descend, and consequently put it out of shape.

Figure 15 shews a mode of forming a junction by making the rafters meet each other, without the intervention of the joggle head, which is usually made to the king post, and of course it has a great advantage over the preceding method.

Figure 1, *Plate* 5, represents another mode of hanging king posts to their principal rafters, which meet each other, as in *figure* 15, *Plate* 4.

Instead of the forked strap, a bolt is used in this case with a spreading head, so as to form a shoulder perpendicular to the rafters, which are notched on purpose to receive it. This has the effect, also, of preventing the rafters of a roof from sinking in the middle. The whole may be made of iron, consisting of two parts connected together by means of a screw, which will draw the tie beam as high as may be required. *No.* 1 is part of the king post with the bolt; *No.* 2 and 3 are parts of the rafters, and *No.* 4, presents a view of the upper edge of the rafters.

Figures 2 and 3, exhibit the most approved forms for the abutments of the braces, at the lower part of the king post.

Figure 2 shews the form of an abutment, when the part which makes the resistance in the direction of the king post is perpendicular to it; and *figure* 3 delineates the form of another abutment, where the part of the shoulders, which make the resistance, is perpendicular to the brace.

In *figure* 4 is shewn a method whereby two braces are connected to an iron king post, which is a small rod of iron, sufficiently strong to bear up the middle of the beam, and to resist the force of the braces by the weight of the middle rafters. The strap which prevents the braces from being pushed downwards, has an eye through each side, and the bottom of the king rod is formed with a cross, equal in length to the thickness of the braces; this cross is perforated in its length to receive the bolt.

Figure 10, *Plate* 6, shews the manner of framing two wall plates, to enable them to receive the hip rafter, with the angle tie and dragon beam, as supports to the rafter.

Figure 7 represents a design for a story post, and breast summers.

With respect to joining timbers sideways, there are an infinite variety of ways by which beams are lengthened; and therefore it would be an endless task to describe every mode which has been proposed. It will suffice to notice those forms only which have been most approved of.

Figure 9, *Plate* 3, represents a method by which a beam may be continued to any length, by building it in three thicknesses.

Figures 10 and 11, present modes of scarfing beams together, and will be found useful in small pieces, which may be glued together. In order to make the joints close, and to render them less dependant on the bolts, and to prevent every possibility of one being drawn away from another, it is proper to indent them together, by the mode called tabling, (which is represented in *figures* 12, 13, 14, 15, 16, &c.); and to leave a small space at the end or meeting of each table, for a wedge. In the operation of joining timbers in this manner, the pieces are first laid so as the joints may be brought as close as possible; the wedge is then driven, while another person strikes the extremity of one of the pieces with a large mallet, which causes the joints to adhere quite close, if they have been fitted well together previous to the operation.

Of the before-mentioned modes, those in *figures* 13, 14, and 15, are the best, because the faces of the tables are parallel to the fibres of the wood, and they are thereby better enabled to resist any longitudinal strain, and with a much greater force. It is necessary, nevertheless, to place plates of iron across the ends of the joints, because more than half of the wood is cut quite through. But less however, is to be apprehended from the tearing of the fibres, by their being drawn in the direction of their length, than from the bending of the bolts.

As the scarfe, in *figure* 14, has several tablings, the extreme wedges are only effective; for a wedge in the middle tends to force the joints open, and consequently only the other two should be fixed. Long scarfings add to the strength of beams; but it has been supposed, that when the numbers of tables is more than two, it is disadvantageous, since the fibres are shortened, and therefore the resistance is less.

Figures 17 and 21, are the two halves of a beam, having tables made in them, in the form of obtuse angles, with a ridge in the middle. These are raised and sunk alternately, and when bolted together, have the appearance of one beam, as is represented in *figure* 22.

Figures 18 and 19, respectively shew the section across the sunk and raised parts; and *figure* 20 represents a section of the beam, when the two parts denoted by *figures* 17 and 21, are bolted together.

When it is necessary for the practical carpenter

to

to scarfe beams after the foregoing method; he should be particularly careful that all the butting places meet closely together. And he should further observe, that in scarfing beams after any of the preceding methods, or by any other modes which his ingenuity may suggest, it would be proper to have every butting joint strapped across with iron on both sides. If this material part be well executed, he will find that it will increase the longitudinal resistance at the weakest section, and diminish, in a great degree, the possibility of the bolts being bent.

Timbers may also be joined laterally, by means of keys and dove tails. This method is truely ingenious, and deserves to be more generally known.

Figure 5, *Plate* 3, presents a longitudinal section of two pieces, joined in this manner, with the dove-tail pieces and the wedge or key, by means of which they are forced against the ends of the pieces required to be fixed. In order to make the one press harder against the other, the interior angle of the dove tail ought to be made greater than the exterior one, formed upon the pieces to be joined.

Figure 6, is a transverse view of the mortise and ends of the dove-tails and keys, on the outside of the piece, and *figure* 7, is also a transverse view of the mortise and ends of the dove-tails and keys, but on the inside part of the piece.

Figure 8, represents a perspective view of the pieces when joined by the keys and dovetails. This excellent method may be adopted in joining parallel pieces together, when the pairs of pieces do not touch each other. The ingenious carpenter, by attending to these principles, will find them useful in many cases, particularly in the construction of wooden bridges.

With respect to joining timbers endways, butting joints are fixed together with bolts, having a screwed nut at each end; one of these nuts must be square, and the other round, the round one must have notches cut close on its edge. The bolt must be let into each piece, perpendicularly to the joint, and the nuts must be sunk from one side across the grain, until the ends of the bolt are enabled to pass the interior screw, which is formed on purpose to receive the exterior one; the square nut is first put in, after which one end of the bolt is firmly driven into the bore, made to receive it, and screwed to the nut. The notched nut is next put in, and the bolt also in its place; after this one piece may be turned round upon the other until the joint is quite close, and two dowels should be introduced one on each side of the bolt. One piece should be driven as close to the other, as the nut will permit, and then with a narrow pointed turn screw, and a mallet, the nut may be forced round until the joint is entirely close.

In the *Second Division* we proceed to describe and illustrate the several parts of constructive carpentry, such as centers, roofs &c. &c.

Centers.—The term center is used to denote a frame of timber, constructed for the purpose of supporting the bricks or stones, during the erection of a vault or arch. The center serves as a foundation for the arch to be built upon, until the work is completed, when it is taken down, or which is technically called struck, and if the arch has been properly constructed, it will stand of itself from its curved figure.

When the span is small, and upon a limited scale, as in vaults and cellars under ground, the foundation of the side walls is dug out, the earth is rounded of in the interval between them, the arch is thrown over upon it; and when the arch is completed, the earth is dug out and removed. But the defects of this method are obvious, and it becomes, therefore, necessary to construct frames of timber for carrying the stones or brick, requisite for the construction of the arch. When the arch is to be constructed above ground, but at no great height above the surface, a frame for supporting the arch stones is easily raised from the ground, and bound together, so as to answer the purpose required, though frequently there is a great waste of wood on such occasions; indeed when the span of the arch is great, or at a great height above the surface of the ground, the expence of a frame formed in this manner, would not only be enormous, but in many cases it would be useless. Whether the arch be great or small, high or low, a proper economy in the wood and workmanship should be observed; since in proportion to the smallest of the expence incurred, will be the increase of advantage to those concerned, and at the same time proportionably greater credit will accrue to the engineer. But it is essential to consider on the other hand, that if in reducing the expense of materials or workmanship, the center should be constructed too slight, and without a due attention to those principles which alone ensure strength, the same may be crushed through the pressure of the arch stones, and the whole fabric may be brought down; the saving in this case will be a poor compensation for so serious a loss, and therefore it may be better, perhaps on the whole, to have too much wood than too little. Under all the circumstances, it behoves the mechanic to obtain the best information that he can on this important subject, which we will endeavour to set in as clear a point of view as possible.

This subject may be very properly divided into three branches, in the first of which, it will be proper to consider the weight to be supported, in the second, the quantity of materials necessary for the support of such a weight, and in the third, the most effective method of applying these materials.

With respect to the first, the weight to be supported on the center is the stones, or brick, of which the arch is to be composed.

It has been determined by several eminent mathematicians, that when the arch is either a semi-ellipsis,

ellipsis, or semi-circle, it can be raised to thirty degrees and upwards without support; after which, it begins to press on the frames composing the center. It should be recollected particularly that this refers only to the semi-elliptical, or semi-circular arch, for if it be a segment of either of the aforementioned curves, it will not only press sooner upon the center, but also more heavily in proportion to the flatness of the arch. If we take for example a semi-circle whose diameter is 20 feet; then, according to the foregoing observation, there will remain 120 degrees of the arch to be supported. Now 120 degrees will measure 20·943 feet, but in order to give the advantage as much as possible to the center, we will call it 21 feet; and if we suppose the arch stones to be of free-stone 18 inches square, whose specific gravity is 2·532, we shall find by the common operations of multiplication, that the pressure on one rib of the center is 7477·307 lbs. avordupoise, or about 66·75 Cwt. From hence may be perceived the necessity of strength and firmness for the center; since each frame must sustain the above weight, not only without warping, or sinking under the pressure, but without rising in the crown, from any weight on its haunches. To pursue this interesting and useful subject still farther, by calculating the increase of weight upon a span of 50 feet; it will be found by the rules of mensuration, that the length of the arch of 120 degrees in a circle whose diameter is 50 feet, is 52·36 feet; for example, we will suppose the arch stone to be 2 feet by 2½ feet deep, which gives 5 superficial feet, and on the supposition that the stone is of the same specific gravity as that before mentioned, the weight supported by one frame of the center, will be found equal to 369·9 Cwt. Hence the weight on the center frame is increased in the proportion of 369·9 to 66·7, or more than five times, besides the allowance necessary to be made for the difference between the stiffness of the center frames; for, on account of the greater extent of the latter center, the frame that would be sufficiently firm at 20 feet, would give way at 50 feet.

In our dissertation on bridges we have made mention of those constructed of iron; and therefore it may not be improper to present to the practical carpenter, an example for constructing of centers for them. We will first examine of what dimensions a center should be if the arch form the segment of a circle, if the span of the arch be 236 feet (being the span of the bridge alluded to in the description of stone bridges), and if the height above the spring of the arch be 34 feet, the diameter in this case will be easily found to be about 444 feet, and the arch stones in this segment would press upon the center frame, at about 18 feet from the spring of the arch. Suppose the arch stone to be 4 feet by 5, which will give 20 superficial feet, and the whole measure of the arch to be 444·15 lineal feet; the solid contents will be found to amount to 4132 feet, and the weight to 318·7 tons, while the weight of the iron employed is 260 tons. Having now taken a view of the weight to be supported, we proceed in the second place to consider, what strength of wood is necessary for the support of such a weight. In determining this, we shall take a view of such experiments as have been made for ascertaining the strength of different materials,

Under the head "Strength of Materials," in the third general division of Carpentry.

We have to consider, in the third place, the most effective method of applying these materials.

It is to be observed, that as an arch in its form, approaches in one part towards the perpendicular, and in the other, towards a horizontal line, the actual weight that it will sustain, lies between that force which a body will carry in the perpendicular, and that which produces a fracture upon any material in the horizontal direction. If the perpendicular be greater than the horizontal line, it will partake more of the strength of the bruising force, than of the transverse fracture; and this species of force may be expressed by the ratio compounded of the bruising or crushing force, and that of the transverse fracture, or more properly, perhaps, it may be termed the absolute and relative force.

It is much to be regretted, that we are not possessed of a sufficient variety of experiments on a large scale, to ascertain the absolute force. At the same time however, it must be admitted that the results of the experiments that have been made, with the observations upon them, will furnish the ingenious carpenter with a tolerable correct knowledge of the principles he may act upon, and also prevent his using superfluous materials, by applying those principles, either to horizontal right lines, to those which incline in a right lined direction, or to curves.

Muschenbroeks asserts, that the weight which crushes one inch of sound oak, is 17300 lbs. but if computed from the increase, or as the squares of the diameters, it is only 16000 lbs. It is well known that the power to break, or make a transverse fracture in the same wood, of the same length, and of different diameters, (if a considerable difference in diameters be taken,) is twice that produced by the square of the diameter. By this comparison we are enabled to judge, that the proportion which exists between the strength of wood and of stone, is 6048 to 17300, or nearly as 1 to 2¼. We are thus enabled to form an estimate of the proportion existing between the arch and the strength of a horizontal line, and we are also enabled to substitute the one material for the other, in point of strength, with sufficient accuracy. Experimentalists agree that a square inch of wood may be pulled asunder, or crushed with a weight of between 16000, and 17300 lbs.; that a piece of wood 18 inches long, and one inch square, may be broken by 406 lbs.; that a piece 12 inches in length, may be crushed by 609 lbs.

lbs.; and a piece 6 inches long, by 1218 lbs. all which circumstances have been proved by the comparison of experiments to be consistent with the principles of the lever. If then, the geometrical mean is taken between the elevation of the arch, as pressure or absolute strength, and the length of the horizontal line, this mean will give the strength of the arch above the horizontal line; for it is clear, that in proportion as the piece of wood may be elevated towards the perpendicular, it will approach so much the nearer to its absolute strength, that in proportion as the arch is flatter, or the piece of wood is less inclined, the nearer it will be to a straight line, and that in proportion as it is the more reduced to its relative strength, the position of the arch must be in the ratio compounded of these two.

The preceding principles may now be applied to the construction of centers of any span, and possessing the strength necessary for the support of the arch.

Pitot, wrote on this subject about the beginning of the last century, and we shall lay his plan of operation before our readers, premising however, that he has been rather too profuse, in the allotment of his materials.

We have already observed, that there is but little or no weight on the centre, until it reaches to about 30 degrees of the arch; at this height, a stretcher is extended from side to side, which stretcher is supported by two struts from the spring of the arch. Upon the upper part of the stretcher, either immediately above, or a little within the upper end of the truss, on each side are two spars connected with the king post, which spring from about the middle of the arch, and divide the stretcher into four parts.

Another strut springs from the rise of the arch, and meets the stretcher at this fourth part, from either side of the arch; these last struts are joined by a tie beam, which gives additional strength to the first stretcher; upon these, on the upper side of the stretcher, two spars join the king post, a little below the other stretcher. The spars are connected together by bridles or cross-spars, from the circular arch, to the lower strut; ribs of a similar formation being placed at proper distances, according to the width of the bridge, and joined by bridging joints, which may be of greater or lesser strength, according to the span of the arch, and the weight it has to support, if no rests are left at the spring of the arch, as a base for the center to rest upon.

Let AB, *Figure 5 Plate 5, of carpentry*, be the ends of two planks, raised from the foundation, on which the center is intended to rest. Let CD, be the stretcher, extended about 35 or 40 degrees from the spring of the arch; or as but little weight rests on the center till it attains that height, the stretcher may be as high as 45 degrees; let also AE, AG, BE, BG, be the two struts on each side; from each extremity of the center, let BE, AE, be fixed to the stretcher near C and D, and AG, BG, at one fourth of CD, let their stretcher or tie beam CG, be equal to one half of CD, the bridles or cross spars 1, 2, 3, &c. from A to C, and from B, to D, are intended to prevent the arch from yielding; from A, to C, and from B, to D. The struts EF, EF, meeting the king post, K. in F, and the interior struts GH, GH, meeting the king post in H, support the bridles 4, 5, 6, on each side of the king post; their use is to stiffen that part of the frame of the center, which supports the upper and more weighty part of the arch.

Pitot intended this center to be used in an arch of 60 feet span; and the arch stones seven feet in length; the weight of a cubic foot he makes 160lbs. As was proposed, we will first consider the weight to be supported by the frame. It is evident in this case, from the figure, that no strain lies upon the frame below C; the arch is raised, or can be raised to this height, before the frame is set, and therefore the perpendicular C c, determines the limit of the absolute pressure upon the centre frame. The part of the arch below C, will rest upon the abutment raised upon the pier: but if there is a pressure upon the lower part of the centre frame, it must be contained between the parallels C c, f g; although it will be admitted, that the arch can be raised to the height C, without the support of the centre frame, and that it will suffer what lies between these parallels, to press upon the frame. To determine the weight of these parts of the arch, the distance between the perpendiculars C c, D d, is 53 feet, the arch stone is 7 feet long, and 3 feet broad, then the weight is $53 \times 3 \times 7 \times 160$ lbs. $= 178080$ lbs.

To determine the area between the two parallels C c, f g, the line f g, perpendicular to the diameter A B, is 13¼, the base is 9½, and C f, perpendicular to it, is 7 feet, the area is 33¼ feet; C c, the base of the triangle C f c, is 7·2; and f c is 7; the area is 25, and the difference is 8¼. If this difference had been the excess of the triangle C f c, above the triangle C f g, it would have been a pressure upon the frame; but as it is the reverse, the pressure is upon the abutment. It is necessary to observe this distinction, in order that an unnecessary expence of materials and labour may not be incurred where it is unnecessary.

It now becomes proper to inquire, what strength of materials is requisite to support this weight.

It has been laid down as a principle that the different pieces of timber composing an arch, act upon each other by their absolute strength; but that they are liable to the transverse fracture, in proportion to the length of the piece. In a span of 60 feet, the length of the piece may be 7 feet, without materially diminishing its strength, in reducing it to the round; and by experiment we learn that the relative strength of 7 feet by 8 inches square is 47649lbs. We know also from experiments, that the strength is

is proportioned to the depth, though care should be taken for so proportioning the breadth or thickness, that the arch may be prevented from warping, the absolute strength being nearly according to the principle of the before mentioned experiment, as the squares of the depth. The absolute strength to the relative force, has been found by some to be in the proportion of 60 to 1, but by others to be only as 42 to 1; the absolute strength of the plank (one inch thick and 12 inches wide) is 189163lbs; if the same were two inches thick, it would still be no more than 189163. But, if it were 8 inches square, then every 7 feet of the arch might be broken with 189163 lbs. weight. We have found, however, before that the whole weight of the arch is only 178080 lbs. which is 11080lbs. less in weight, than that part of the frame is capable of bearing, and as 7 feet is only about one seventh part of 53; the frame is sufficiently strong to support the entire weight of the arch, when that weight is divided equally along its whole length. This is not the case with the center frame of an arch, as it is loaded at one place, and not at another; it is therefore apt to yield between the parts where the weight is heaviest, the form of the arch is consequently changed; for the center frame is not limited merely to supporting the arch, but to keep and preserve it in its true form, and therefore some struts may be necessary to prevent its putting the arch out of shape. To remedy this, where the arch begins to press upon the frame at C, draw the cord line C c, *Figure* 6, which acts as a tie beam to the arch from C, at 55 degrees, to c, at 51 degrees; as beyond this, if the arch frame has altered its form, it will require it, at least, the force of the tie will have a tendency that way. At that part of the arch, where its weight begins to flatten the frame, as at 2, draw the stretcher 2 2, which likewise acts as a tie beam, while it affords support to the bridle 1, on one side, and to 3 the bridle on the other side, from D d; and thus the arch c d, is prevented from sinking by the tie beams c d. This will effectually prevent any yielding of the frame, notwithstanding the immense pressure of the materials composing the arch.

The relative proportions of the strength of oak and fir, have been nearly ascertained by experiments made by different philosophers, though the results of these experiments do not in all instances exactly agree. We will take that of Buffon, which is 3-5ths. Now to reduce a frame of oak, to one of fir of equal strength, divide 8 inches, the diameter of the oak, by 3-5ths. the relative strength of fir, which gives 1 1-3rd. inches. If we allow $1\frac{1}{4}$ inches, then the depth of the frame will be $9\frac{1}{4}$ by $2\frac{1}{2}$ inches. In this way the strength of the fir arch is rendered equal, and by the additional allowance, superior to the oak in strength, at a less expence in wood and workmanship.

M. Pitot allowed the rings of his arches to consist of pieces of oak, 12 inches broad and six thick. The stretcher CD, is 12 inches square; the straining piece CG, is likewise 12 inches square; the lower struts are 8 inches by 10; the king post is 12 inches square; the upper struts are 10 by 6; and the ridges are 20 by 8 old French measure; which dimensions may be very easily accomodated to English measure, by observing that the old French inch is equal to 1·0657 English inches.

Pitot allows the square inch to carry 8650lbs. that is, one half of the absolute strength, which is ascertained by experiment to be about 17300lbs. and not the square of the diameter, which would be only 16000lbs. But on account of knots he reduces it to 7200lbs. per inch. He then computes the whole load upon the frame to be 707520lbs. which is the weight of the whole arch stones, supposing each stone to be 3 feet broad, and the whole to press upon the frame, which comes very near. Pitot also supposes the weight that rests upon the center to be 11-14ths. of the whole weight, but assigns no reason for his conjecture. Mr. Couplet assumes that it presses by 4-9ths. Our readers, however, have it in their power to examine the principles, and judge for themselves.

Figure 7, represents a second form of a center frame, which is described by Pitot, and is adapted to an elliptical arch. Its construction differs in no respect from the former, except only that the two upper struts are parallel; the strength, as in the former, is superabundant.

Both this and the preceding are capable of being divided into three pieces, which circumstance renders them more easy to be managed when erecting, particularly in large spans.

Figure 8, exhibits a mode of constructing a center, which is neat and ingenious; but there is much more wood and workmanship expended than is necessary. It is divided into two parts, the base or stretcher L, L, of the upper part, resting upon the lower part of the frame, by which the greatest part is rendered quite superfluous. The lower rests, EF, appear to be necessary only in preventing the stretcher L, L, from yielding, and thereby allowing the arch to lose its true curvature.

The general maxim of construction adopted by Perronet, a celebrated French architect, was to make the truss consist of several courses of separate trusses, acting independently, as he supposed, of each other, by which mode he sought to avail himself of the united support of them all. Each truss spanned over the whole distance of the piers, and consisted of a number of struts, set end to end, so as to form a polygon. By this ingenious construction, the angles of the ultimate truss lie in lines pointing towards the centre of the curve.

Figure 9, represents the centering of the bridge of Cravant, the arches of which are elliptical.

The longer axis or span is 60 feet, and the rise 20 feet. The arch stones weigh about 176lbs. per foot,

and

and are four feet in length, which is the thickness of the arch The truss beams were from 15 to 18 feet long, and 8 inches broad, by 9 inches deep. The entire frame was constructed of oak; the trusses were five in number, and set $5\frac{1}{2}$ feet apart; and the entire weight of the arch was about 600 tons, or about 112 tons on each truss. Ninety tons of this must be allowed to press the truss; but a great part of the pressure is sustained by the four beams which form the feet of the truss, and are joined in pairs on each side. The resultant of the parallelogram of forces for these beams, is to one of the sides as 360 to 285.

Hence then 360:285::90:$71\frac{1}{4}$ tons the weight on each foot, and the section of each is 144 inches; three tons may therefore be laid with perfect safety on every inch; and the amount of this is 432 tons, which is six times more than the absolute pressure on the foot beams in their longitudinal direction. The absolute strength of each foot beam is equal to 216; tons but from their being more advantageously situated, the resultant of the parallelogram of forces which corresponds to its position, is to the side as 438 to 285. This is equal to 58 3-5ths. tons for the strain on each foot; which is not much above one fourth of the pressure it is capable of bearing. It is evident therefore, that this kind of centering possesses the advantage of superabundant strength. The upper row of struts is sufficient, and nothing is wanting but to procure stiffness for supporting them

Figure 10, represents the center constructed by Hupeau, for the bridge of Orleans, which is allowed to be one of the boldest centers ever executed in Europe. The form of the arch is elliptical, with a span of 100 feet, and a rise of 30 feet; and the arch stones are six feet in length. It is but justice to remark that the long beams AB, on each side, were introduced by Perronet, who was appointed architect on the decease of Hupeau; before the beams AB, were introduced, the centre rose and sunk at the crown.

We have now taken a view of the methods adopted by French architects, in the construction of centers, and of their effects; let us now proceed to consider those which have been constructed in our own country. The first that presents itself is the one made use of for Blackfriars-bridge, a delineation of which appears in *Figure* 11. The span in this instance is 100 feet, and the form elliptical; the arch stones from the haunches are 7 feet; but near the key stones they are not quite so much, as they decrease in length from the haunch to the key stone.

The principles of this center will be easily seen from a view of the figure; it consists of a series of trusses each supporting a point in the arch, the principal braces having their lower extremities abutting below, at each end of the centering, on the striking plates, and at the upper end, upon apron pieces, which are bolted to the curve that support bridgings, for binding the pieces which compose them together at their junction. This center labours under a great disadvantage, from the frequent intersection of the principal braces with one another. The ingenious Mr. Mylne, made use of the following method of easing or disengaging the center frame from the mason's work. Each end of the truss was mortised into an oak plank cut in the lower part as in the figure, a similar piece of oak was placed to receive the upper part of the posts. The blocks rested upon these posts, but where not mortised into them, pieces of wood being interposed instead. The upper part of these pieces was cut similar to the lower part of the other; the wedge E intended to be driven betwixt them, was notched as the figure shews, and filled up with small pieces of wood, in order to prevent the wedge from sliding back by the weight of the arch; which not only appears from the figure as a likely circumstance, but eventually happened.

When the time for striking the center arrived, the inserted pieces of wood were taken out, and the wedge, (prepared for driving back, by being girt with a ferule round the top,) was removed by a piece of iron driven in with the head, so broad as to cover the whole of the wood. A plank of wood after being sheathed with iron, in the same manner at the one end, was suspended, so that it could act freely in driving back the wedge to any distance, however small, and with certainty. Thus by an equal gradation, the center was eased from the arch, which appeared to have been so equally supported throughout the whole of the operation, and the arch stones so properly laid, that it did not sink above one inch.

We shall now suggest some hints which may be found useful in the construction of trussed arches, and tend to remedy the faults and failures that have occurred in practice.

In navigable rivers, or in those which are apt to be swollen by rains or other causes, trussed arches for center frames, are found expedient. In arches where there is no such danger, the frame may be properly secured by posts, from below, which are made to abutt on those parts of the arch where the greatest strain must fall.

In the centers used by Pitot, we have already complained of an unnecessary expenditure of wood and workmanship. We have also shewn the comparative strength of oak, and fir wood, for the rings of his frames, which alone ought to have the strength required, in order that they may be fully adequate to support the weight; but as this weight must be gradually applied, the frame should likewise have such a degree of firmness, as to form the exact mould of the arch intended, and, for this purpose, it must be prevented from yielding in any part. Now, as we have already observed, that the frame supports no part of the arch, until its rise from the spring

spring, to about 35 degrees, if a semicircle, and so in proportion for a segment thereof, and, in an ellipsis, to a part corresponding with the nature of that curve; the supporting struts and ties can be more particularly directed to support that part of the arch, which bears with the greatest strain upon the center. In *Figure* 6, *Plate* 5, where the necessary strength for Pitot's arch, is pointed out, the frame of fir, requisite to stiffen the frame, is $9\frac{1}{2}$ by $2\frac{1}{4}$. The tie beam C c, is joined to those parts of the arch where the strain from being greatest, tends most to raise it in the crown. The length of this tie beam being 25 feet, and its size $9\frac{1}{2}$ by $2\frac{1}{4}$, would require a weight of 30495 lbs. to make the transverse fracture; but one third of this, at the bridle 1, 3, is sufficient to resist the strain at that part of the arch.

Figure 7, is Pitots centering for his elliptic arch; the strength of *Figure* 6, may answer for this, by giving the ring and tie beams half an inch more depth.

Figure 9, represents the centers used by Perronet in erecting the bridges at Nogent and Mayence.

The center used at Nogent, was 90 feet span, and 28 feet high; the centers used at Mayence, was of greater dimensions, and we shall therefore here consider the weight to be supported. The arch from A to C, measures 42 feet, and the arch stones $4\frac{1}{2}$; now admitting the arch stones to be 3 feet broad, they would amount to 567 solid feet, which, at 160 lbs. per foot, is equal to 90720 lbs. This is but little more than one half of the semi-circular arch; and, although it is flatter, the weight is so much the less, that no additional strength is necessary to be given to the frame delineated in *Figure* 6, for the 60 feet span. The strength of the materials for the 90 feet arch, is likewise sufficient; that it may be rendered more stiff, on account of its greater extent, a tie beam 1, 4, 3, 4, may be added on each side of the arch, as is represented by the dotted line.

In the centering used by Perronet, it appears that notwithstanding the superabundance of wood employed, the frame was so much affected, and rose and sunk so much, that the arch deviated considerably from its intended form.

We have already observed, that *Figure* 10 is the center frame of the bridge of Orleans, which was commenced by Hupeau, but finished by Perronet. During the completion of the work by the latter, he found the arch and frame give way, for which reason he strengthened the center frame, by continuing the strut. By forming the base of the triangle 1, 2, 3, on each side, his frame was rendered sufficiently stiff, and the inner part below A B, A B, became entirely superfluous. The weight that presses on the arch is great, owing to the length of the arch stone, and the flatness of the arch. That part of the arch which presses, contains about 57 degrees, and measures 88 87 feet. Hence, admitting the length of the arch stone to be 6 feet, and its width 3, we find the solidity =1596·6, and its weight, (supposing as before, the weight of a solid foot =160lbs.) to be 255456 lbs. The length of each plank of the truss being 7 feet, and its other dimensions 12 by 2, the strength is 189163 lbs. The weight for every 7 feet in length of the arch, is one third of this, viz. =63054 1-3rd lbs. and in 88 feet, there are 756652 lbs. to support 255456 lbs. which renders the arch more than three times stronger, without making any allowance for the strength of the arch, being the mean of the splitting force and transverse section; the tie beams will be of great use in stiffening the frame.

Figure 12, represents the center for Tongueland bridge, the span of which was about 105 feet.

Figure 13, exhibits the center used for Conon bridge, which was about 55 feet span, and *Figure* 14 shews the mode of centering for Ballater bridge, the span of which was about 50 feet.

Figure 15, is an excellent design for a center, which well merits the attention of the ingenious carpenter.

From the examples adduced, and the observations made on them, it must appear evident, that center-frames may be constructed of a greater extent than any hitherto used, and with sufficient strength to support almost any mass of materials, necessary for the construction of an arch. It may now be asked, perhaps, why the use of these frames is not continued. It may be objected to this, by the advocates for stone bridges, that stone is more durable, and elegant, and when once constructed, is free from the various trusses and tie beams, so necessary in the wooden frame. The advocates for carpentry must admit that wood is not as durable as stone; but they have it in their power to prove that bridges can be constructed of wood at a much less expence than those of stone, and that when they fail in any part, they may easily be replaced again, at a small expence, and made even to last longer than a stone arch. As to neatness and elegance, the frame of wood may be so constructed, as to vie with, if not surpass the arch of stone. In order to support this assertion, let *Figure* 1, *Plate* 6, *of carpentry*, represent a semi-circular arch, of 60 feet span, with the under arch composed of pieces 5 feet long, 12 inches deep, and 2 inches thick, and the upper arch of the same breadth and depth, joined to the former in close contact, so as to form breaking joints, with the several pieces of which the two arches are composed. The absolute strength of this arch, before the two trusses are joined, is upwards of 84 tons, which is more than three times the weight that can be brought upon it; and hence, there is not the least occasion for placing struts below the arch, in order to stiffen it, for it can be stiffened to a much greater advantage above the arch. This however, is not practicable in center frames. Let C D E F, be the road way, supported by the perpendicular pieces

1,

1, 2, 3, &c. As the carriage acts upon these, obliquely, transepts from the arch in a radial direction, give them the advantage of equal pressure upon the arch. Each of these perpendicular pieces is mortised into short pieces, which arrange themselves into an arch. These short pieces all abutt one upon another, and forming a fillet over the arch, project so far, that the architraves of any order may be placed along the face of the arch, which will add both to its strength and ornament. By these means a rib is formed, 12 inches deep, and 4 thick, with a fillet 4 inches deep, and 6 inches broad, extending over it, to cover the face of the architrave. Admit the arch to be 42 feet wide, then 7 of these ribs will not be inferior in strength to stone, or any metal: but it may be said, perhaps, that they cannot be so durable. It is well known how long wood has lasted in roofs, and joists of flooring, and even when it forms a part of the wall of a house built of brick. The interstices between perpendicular bearings of the wood may be built up either brick thick, or brick on edge, which will not only render its preservation equal to what it is in a house, but protect it also from the bad effects of being alternately wet and dry, the lower parts of the ribs may be covered with a thin lining. In order to observe any failure or decay in the wood, a door may be left in the side, whereby it may be repaired without interrupting the passage over the bridge.

The covering before mentioned, ought to be laid in such a manner as to prevent the water from penetrating through, to the injury of the bridge. From the proportional strength of fir and oak, we know that a fir plank of 13½ inches, is equal in strength to oak of 12 inches. Therefore, an arch of wood, does not much exceed the expense incurred in framing a center, either for a stone, or an iron bridge, and certainly it will not be inferior to either of them, in the points of beauty, elegance, or ingenuity.

The span here proposed is only 60 feet, but an arch of 500 feet may be required, which must have a center calculated to support the superior weight, and preserve the intended figure. Notwithstanding this increased size of the span, the center frame can be made of strength sufficient to support the superior weight, since it can be rendered stiff by the same method as has been proposed for the 60 feet arch. Such a bridge as this will support any weight that can be laid upon it, and may be formed of any figure, preferred by the architect. Or it may be framed in a manner similar to bridges formed of iron, but it is reasonable to suppose, that one arch over the other will be equally strong, and more easily preserved from the weather, when constructed in the way before described.

The joints may be secured from opening, by inserting dove-tailed pieces across the joints on the inside of the rib, and the abutments will prevent the ends of the arch from flying out. In consequence of the pressure coming upon the arch obliquely, it may be said to have a tendency to rise at the crown, especially when of a great span; the only method of preventing this in the center frame, is by struts and tie beams applied judiciously. By these the rise may be prevented more effectually, without destroying the effect of the ornamental part of the arch. In the abutment which must be constructed of masonry, beams should be let securely into the wall, with their ends projecting one foot, (as represented by G and K,) and placed so as to correspond with each rib of the road way formed by the beam DE.

The tie beams GD, KE, should be joined to these, in such a manner as the Carpenter may deem most secure; and from these tie beams, radial struts should be mortised into the fillets at G, K, as we have before mentioned, instead of the perpendiculars joining the road way CDEF, and resting on the tie beams GD, KE, supported by the radial struts 4, 5, 6, as represented in the figure. It must now appear evident, that the crown of the arch cannot rise without lifting up, and removing the masses which form the abutments at each end; and that it cannot sink until the weight laid upon it, absolutely crushes the materials of which the arch is composed. Thus a neat and elegant arch is obtained, that may, at a small comparative expence, be kept up during the revolutions of ages.

In the article bridge we presented several very excellent designs from the works of Palladio, which merit the notice of all those who wish to excel in this elegant art.

In addition to these, we have added some other forms of wooden bridges as exhibited in *Figures* 11, 12, 13, 14, 15, and 16, of *Plate* 6.

In the whole of the preceding designs, there is much room for the display of skill in the proper adjustment of the scantlings of the timber, and the obliquity of the braces to the lengths of the different bearings. A very oblique strut, or a slender one, will suffice for a small load, and may often give an opportunity to increase the general strength; while the great timbers, and upright supports, are reserved for the main pressures. Nothing will improve the composition so much, as reflecting, progressively, and in the order of these latter examples. This alone can preserve the great principle in its simplicity and full energy.

These constructions may be considered as the elements of all that can be done in the art of building wooden bridges, and are to be found, more or less obvious and distinct, in all attempts of this kind.

In the same article also (*Bridge*) we alluded to the ingenious mode of centering proposed by Mr. Telford, in his "report to a committee of the House of Commons, on the construction of a bridge over the

the Menai." We shall here make such extracts from this report, as may be found applicable to the subject." Hitherto the centering has been made by placing supports and working from below, but here I propose to change the mode, and work entirely from above; that is to say, instead of supporting, I mean to suspend the centering." (By inspecting *Figure* 2, *Plate* 6, *of Carpentry*, the general principle of this will be readily conceived, and *Figure* 3, shews the center frame on a larger scale.)

"I propose, in the first place, to build the masonry of the abutments as far back as AB, CD, and in the particular manner shewn in the section."

"Having carried up the masonry to the level of the road way, I propose, upon the top of each abutment, to construct as many frames as there are to be ribs in the centers, and of at least an equal breadth with the top of each rib. These frames to be about fifty feet high above the top of the masonry, and to be rendered perfectly firm and secure. That this can be done, is so evident, I avoid entering into details respecting the mode. These frames are for the purpose of receiving strong blocks, or rollers and chains, and to be acted upon by windlasses, or other powers."

"I next proceed to construct the centering itself: it is proposed to be made of deal baulk, and to consist of four separate ribs, each rib consisting of a continuation of timber frames, five feet in width across the top and bottom, and varying in depth from twenty-five feet near the abutment, to seven feet six inches at the middle or crown. Next to the face of the abutment, one set of frames, about fifty feet in length, can, by means of temporary scaffolding and iron chain bars, be readily constructed, and fixed upon the masonry offsets of the abutment, and to horizontal iron ties laid into the masonry for this purpose. A set of these frames, (four in number), having been fixed against the face of each abutment, they are to be secured together by cross and diagonal braces; and there being spaces of only six feet eight inches left between the ribs, (of which these frames are the commencement,) they are to be covered with planking, and the whole converted into a platform fifty feet by forty. By the nature of the framing, and from its being secured by horizontal and suspending bars, I presume every person accustomed to practical operations, will admit that these platforms may be rendered perfectly firm and secure."

"The second portion of the centering frames having been previously prepared and fitted together in the carpenter's yard, are brought in separate pieces, through passages purposely left open in the masonry to the before mentioned platform. They are here put together, and each frame raised by the suspending chain bars, and other means, so that the end which is to be joined to the frame already fixed, shall rest upon a small moveable carriage. It is then to be pushed forward, perhaps upon an iron rail-road, until the strong iron forks which are fixed upon its edge shall fall upon a round iron bar, which forms the outer edge of the first, or abutment frames. When this has been done, strong iron bolts are put through eyes in the forks, and the aforesaid second portion of frame-work is suffered to descend to its intended position, by means of the suspending chain bars, until it closes with the end of the previously fixed frame like a rule-joint. Admitting the first frames were firmly fixed and that the hinge part of this joint is sufficiently strong, and the joint itself about twenty feet deep, I conceive that even without the aid of the suspending bars that this second portion of the centering would be supported; but we will for a moment suppose that it is to be wholly suspended. It is known by experiment, that a bar of good malleable iron, one inch square, will suspend 80000lbs. and that the powers of suspension are as the sections; consequently a bar of one inch and a half square will suspend 180000lbs.; but the whole weight of this portion of rib, including the weight of the suspending bar, is only about 30000 lbs, or one sixth of the weight that might be safely suspended. And as I propose two suspending chain bars, to each portion of rib; if they had the whole to support, they would only be exerting about one-twelfth of their power, and considering the proportion of the weight which rests upon the abutments, they are equal also to support all the iron work of the bridge, and be still farther within their power."

"Having thus provided for the second portions of the centering a degree of security, far beyond what can be required; similar operations are carried on from each abutment, until the parts are joined in the middle, and form a complete centering, and being then braced together, and covered with planking, where necessary, they become one general platform, or wooden bridge, on which to lay the iron work."

It is, I presume, needless to observe, that upon such a centering or platform, the iron work, which it is understood has been previously fitted, can be put together with the utmost correctness and facility; the communications from the shores to the centering, will be through the before mentioned passages left in the masonry."

When the main ribs are fixed, covered, and connected together, the great feature of the bridge is compleated, and "when advanced thus far," (proceeds Mr. Telford.) "I propose (though not to remove), yet to ease the timber centering, by having the feet of the centering ribs, (which are supported by offsets in the masonry of the front of the abutment), placed upon proper wedges; the rest of the centering to be eased at the same time, by means of the chain bars. Thus the hitherto dangerous operation

tion of striking the centering, will be rendered gradual, and perfectly safe; insomuch, that this new mode of suspending the centering, instead of supporting it from below, may, perhaps, hereafter be adopted as an improvement in constructing iron bridges, even in places not circumstanced as are the Menai Straights. Although the span of the arch is unusually great, yet, by using iron as a material, the weight upon the centre, when compared with large stone arches, is very small, taking the mere arch stones of the centre arch of Blackfriars-bridge at $156 \times 43 \times 5$, equal to 33540 cubic feet of stone, it amounts to 2236 tons; whereas the whole of the iron-work in the main ribs, cross plates, and ties, and grated covering plates, that is to say, all that is lying on the centering at the time it is to be eased, weighs only 1791 tons. It is true, that from the flatness of the iron arch, if left unguarded, a great proportion of this weight would rest upon the centering; but this is counterbalanced by the operation of the iron ties in the abutments, and wholly commanded by the suspending chain bars."

The ingenious Mr. J. W. Boswell, has proposed six different modes of constructing centering frames for arches, between abutments and piers, without any support from piles or props beneath, in the 116th number of the Repertory of Arts.

Mr. Boswell observes, that "the first ideas on this subject, occurred (to him) from perusing Mr. Telfords plan for building an iron bridge over the Menai, for which he proposes to form centering without any scaffolding, from beneath, in a method highly ingenious, and of great boldness and originality of design." Mr. Boswell further observes, "that the plans proposed by him, were intended as a farther extension of the idea, to situations in which Mr. Telford's plan would not be applicable, and to afford greater facility, and less risk in the execution; in doing which, (he says) I have not the smallest intention to infringe on what Mr. Telford has already done."

Roofs.—The uppermost part of a building. The roof, properly speaking, comprises the timber work, with the covering of slate, tile, lead, tessera, &c. &c. though carpenters usually restrain the application of the word to the timber work only. The forms of roofs are various; sometimes they are pointed, and sometimes they are square, that is, the pitch or angle of the ridge, forms a right angle, whereby it is a mean ratio between the pointed and flat roof, the latter of which, is in the same proportion as a triangular pediment, and is chiefly used in Italy, and the hot countries, where falls of snow but rarely occur. Sometimes roofs are made in the pinnacle form; sometimes they have a double ridge, and sometimes they are mutilated, that is, they have a false roof, which is laid over the true one; sometimes again they assume the shape of a platform, (a shape mostly adapted in buildings in the east, and sometimes they are truncated, that is, instead of terminating in a ridge, the ridge is cut square off at a certain height, covered with a terrace, and encompassed with a balustrade. In some cases, roofs are formed so as to resemble a dome. When the walls have been raised to the intended height, the vaults made, the joists laid &c. then the roof is to be raised, which embracing every part of the building, and with its weight equally pressing upon the walls, not only operates as a band to all the work, but protects the inhabitants from rain or snow, the burning heat of the sun, and the moisture of the night, and is of no small advantage to the building itself, in casting off the rain from the walls. It is generally allowed, that the Greeks excelled all nations, in taste, and gave the most perfect models of architectural harmony, within a certain limit, yet they never erected a building which did not exhibit the roof in the most distinct manner, and though they borrowed much of their model from the orientals, they introduced that form of roof, which the particular nature of their climate pointed out as the best adapted for sheltering them from the rains. The roofs in Persia and Arabia are flat, while those of Greece, are without exception, sloping; is it not therefore, a gross violation of the true principles of taste in architecture, (as practised in the regions of Europe,) to take away, or endeavour to hide the roof of a house? And to what can it be ascribed, but to that rage for novelty which now so unfortunately domineers over the minds of the rich? Our venerable ancestors seemed to be of a very different opinion, and were accustomed to ornament their roofs, as much as any other part of the building, it must be allowed certainly, that they offended against the maxims of true taste, when the gave to this part of a house, (the roof,) the external marks of elegant decoration, which every spectator knew, contained nothing more within than a garret; but their successors, no less offend, by so effectually hiding the roof with a screen, as to render it doubtful whether the house has a roof or not.

To be brief, when a house is to be built, ornament alone will not effect the purpose; a covering must be raised, and the enormous expence, and other great inconveniences which attend the concealment of this necessary protection, by parapets, ballustrades, &c. have compelled architects to consider the pent-roof as inadmissable and how its form may be best modified. An unprejudiced man would be determined in this, by the adaptation of a particular form to the meditated purpose. A high pitched roof will, undoubtedly, shoot off the rain and snow better than one of a lower pitch. The wind will not so easily blow the dropping rain, between the slates, nor will it have so much power to strip them off. A high pitched roof operates with less pressure on the walls, not only from the strain being less horizontal, but from its admitting of a lighter covering

ing. It is, however, more expensive, since it requires timbers of greater dimensions to make it equally strong, a greater quantity of materials is necessary to cover it, and it exposes a greater surface to the influence of the wind. Very great changes have taken place in the pitch of roofs; our ancestors made them very high, and we form them very low, it may now be reasonably asked whether this diversity has been altogether the result of good principles? This does not appear to have been the case, and it must be confessed that from its being the professed aim of our architects to make merely a beautiful object, without considering its advantages, or disadvantages, it is almost vain to look for principle in the rules adopted by them. A rivalry seems to have existed in former times between Carpenters and Masons. Many of the baronial Halls are roofed with timber; and the carpenters appeared to have borrowed a great deal of knowledge in their construction from the masons, as their wide roofs are frequently found to have been put together with great judgment and ingenuity. Their professed aim was to throw a roof over a very wide building, with as moderate a consumption of timber as possible.

Roofs have been constructed 60 feet wide, although there has not been in them a piece of timber more then 10 feet long and 4 inches square. The roof is in fact that part of a building which requires the greatest degree of skill, and where the exhibition of science is more wanted than in any other part. The task of constructing the roof devolves generally upon the carpenter; the architect seldom knowing much of the matter. The framing of a great roof is considered by the ingenious and scientific carpenter, as the very touchstone of proficiency in his art; and there is nothing that tends more to shew his fertility of judgment and his knowledge of the principles of his profession. A clear view of the principles on which the construction of roofs depends, (so that they may gain all the strength and security that can be desired, without an extravagant expence of wood and iron,) cannot but be acceptable to the inquisitive artist. It must be acknowledged, that the framing of carpentry, whether for roofs, floors, or any other purpose, affords one of the most elegant and satisfactory applications which can be made of mechanical science to the arts of common life. The practical carpenter unfortunately, however, is generally ignorant even of the elementary principals of mechanical science, and too frequently our most experienced carpenters have no other knowledge of their business, than what arises from experience and natural sagacity; under such circumstances, what can we expect, but that works, framed by those who possess only superficial knowledge of their profession, should either tumble down, or fall into a state of premature decay.

Under this head, we shall endeavour to give an account of the leading principles of this particular branch of carpentry, in a familiar manner, taking for our guide only the simple properties of the lever, and the composition of motion.

A knowledge of these will enable the artist to dispose his materials to the best possible advantage, with respect to the strains to which they are exposed, so as always to know the amount of strain which each individual piece may have to bear.

To effect this desirable purpose, it depends on the principles which regulate the strength of the materials, on the manner in which this strength is exerted, and the mode in which the strain is laid on the materials. With respect to the first, we shall refer our readers to the article, *Strength of materials* at the end of this treatise; contenting ourselves here with a few passing observations.

The force which resists the breaking, crushing or the dividing asunder of the materials composing floors, roofs, and framings of every kind, arises either from the immediate or final cohesion of the particles which form that force. We will illustrate this by a simple experiment; when a weight is suspended by a rope, this weight either tends to break or disunite all the fibres of the rope, or it tends to separate or divide some of the fibres from the rest. It is evident that this union amongst the fibres is produced by twisting, which causes them to adhere to each other so closely, that any one fibre will break rather than quit the part where it was originally placed. The ultimate resistance arises therefore from the cohesion of the fibres, and the force or strength of all fibrous materials, is exerted in a similar manner; since the component parts are either broken or pulled out from amongst the rest.

Hence we deduce, that the proper measure for the strength of a rope, or a piece of any other material, is the force required in order to break it. The separation of the fibres is the most simple strain to which they can be exposed, this strain being just equal to the sum of the forces which, are necessary for breaking or disengaging each fibre.

On the contrary, when solid bodies are exposed to great compression, they can resist only in a certain degree; for we know from experiment that a piece of lead or clay when compressed will be flattened; that a piece of chalk or freestone will be crushed to powder; and that a beam of wood will be crippled, that is, it will swell out in the middle, and its fibres will lose their mutual cohesion, when the piece may be easily crushed by the pressure on it.

A piece of matter of any kind may also be destroyed, by wrenching or twisting it; and a beam or a bar of metal, or a piece of stone, or any other substance may be broken transversely. We may illustrate these circumstances from a joist or rafter supported at the ends when it is overloaded, or from a beam of any sort fastened by one of its ends in a wall, with a weight or pressure laid on its projecting part.

In

In this last case, however, a transverse fracture will be the result by the weight of the beam itself, should the projecting end be unsupported. This is the species of strain to which the timbers of roofs are most commonly subjected; and, unfortunately, it is that kind of strain which they are the least able to bear.

This is a case which demands the full exercise of the judgement of the carpenter, and against which he must chiefly guard, by endeavouring to avoid the strain in every possible instance, or at least by diminishing it as much as is within his power. We again, however, refer the reader to the article, *Strength of materials*, for more information on this particular point.

Mr. Couplet of the Royal Academy of Paris, has given a masterly solution of the problem for determining the best form, of a kirb roof but the following one, taken from the Encyclopædia Britannica, we shall insert here on account of its elegance.

Let A E, *Figure* 1, *Plate* 11, represent the width, and C F, the height; and it is required to construct a roof, A B C D E, whose rafters A B, B C, C D, D E, are all to be equal, and which shall be in equilibrio.

Join CE, and bisect it in H, and draw GH perpendicular to CE, meeting A E, in G, and with this point as a centre and distance, G E, or G C, (for they are equal) describe the circle E D C; draw H K, parallel to F E, meeting the circumference in K, draw C K, cutting G H in D; join C D, E D, and they will represent the rafters of half the required roof, and the other side may be constructed in the same manner.

For the satisfaction of our geometrical readers, we shall explain the preceding construction. We know that the proportion resulting from the equality of the rafters, and the extent of surface throughout the uniform roofing, which they are supposed to support, is, that the loads in the angles C and D, are equal; hence, let E D, be produced till it meets the vertical line F C, in N; draw also, B P, parallel to C D, meeting the same line in P, and join P D, when it is evident, that BC DP, is a parallelogram; let its diagonal B D, be drawn so as to intersect C P in R, then divide it into two equal parts, C R, R P, because C P, is the other diagonal of the parallelogram.

Produce K H, to meet C F, in Q, which will be bisected in that point, since CH is equal to HE, and H Q parallel to F E; join K F, which is evidently parallel to D P, and make C S, perpendicular to C F, and equal to F G; and from the point S, with the distance S F, describe the circle F K W. It will pass through K, because S F is equal to C G, and C Q =Q F, join W K, W S, and produce B C, so as to cut N D, in O.

It is now apparent, that the angle W K F, at the circumference, is one half of the angle W S F, at the centre, and is consequently equal to W S C, or C G F, and double the angle C E F, or E C S; but E C S, is equal to the sum of E C D, and D C S, and E C D is one half of N D C, and D C S one half of D C O, or C D P, therefore the angle W K F, is equal to N D P, and W K, parallel to N D, and C F is to C W, what C P is to C N, but C N is equal to C P, and both are to each other, as the loads upon D and C; these are necessarily equal, and the frame A B C D E, is in equilibrio.

The intelligent artist will readily adapt this construction to any proportion between the rafters, CD, DE, which other circumstances, such as garret rooms, &c. may require. It must be constructed so that NC may be to CP, as CD, to $\frac{CD+DE}{2}$.

He must be careful, also, to have the inclination or slope of the upper rafters CB, CD, sufficient to prevent the penetration of rain, and the effect of high winds, when the roof is intended to be covered over with slates, tile &c. The only circumstance left for choice in this case, is the proportion of the rafters AB, and BC; but nothing can be more easy than to make NC, bear any required proportion to C P, when the angle B C D is given. The truss for a roof should always be in equilibrio; when this is the case, the whole force of the struts and braces, (which are introduced in order to preserve its form), will act as it ought, without being expended in any one part more than may be necessary.

We will now proceed to lay down some general rules, agreeably to which all roofs should be constructed. In doing this we shall consult brevity as much as possible, by exhibiting only the principal and most useful form of roofs; and particularly the mode of throwing a roof over a very wide building, without any intermediate support.

The most simple mode of constructing the frame of a roof intended to consist of two rafters AB, and BC, meeting in the ridge B, is shewn at *Figure* 2. Though this is certainly the most simple form for a roof, it is frequently, however, constructed wrong. We have already seen, that when the weight of any portion of covering is given, a steeper roof requires stronger rafters; and that when the scantling of the timber is given, the relative strength of a rafter is inversely as its length. The ingenious Mr. Muller, has determined that the square pitch is the best for a roof; but motives of economy have induced Carpenters to prefer a low pitch; for, although a low pitch diminishes the support given by the opposite leg faster than it increases the relative strength of the other, yet this is not of material consequence, since the remaining strength of the opposite leg is still very great; because the supporting leg has to bear up only against compression, from which circumstance, it is a great deal stronger than the supporting leg acting against a transverse strain.

This roof answers its purpose but seldom, owing to its

its thrust on the walls, which is the most hazardous and dangerous of all strains. The generality of walls require ties to keep them on foot, and consequently it must be injudicious to subject them to any considerable strain, pressing outwards. When we reflect on the height and thinness of the walls of even a strong house, we may justly feel surprised that they are not thrown down by every strong gust of wind; and this undoubtedly would be the case, if they were not stiffened and secured by the cross walls, joists, and roof, all of which co-operate, in keeping the different parts of the building together.

The following is Mr. Mullers solution to this interesting problem. Describe on the width A C, *Figure* 3, the semicircle AFC, and bisect it by the radius FD. Produce the rafter AB, to the circumference in E, join EC, and draw the perpendicular EG. Now A B : A D :: A C : A E, and therefore, $A\ E = \frac{A\ D \times A\ C}{AB}$ and A E, is inversely, as A B, and may therefore represent its strength, in relation to the weight actually lying on it. Also the support which C B, gives to A B, is as C E, because C E, is perpendicular to A B. Therefore the form which renders $A\ E \times E\ C$, a maximum seems to be that which has the greatest strength. But AC:AE:: EC:EG, and $E\ G = \frac{AE \times EC}{A\ C}$ and is therefore proportional to $A\ E \times EC$. Now, E G is a maximum when B is in F, and a square pitch is in this respect the strongest.

The consideration of horizontal thrusts, creates the necessity of their being counteracted by other forces; under this impression, the carpenter introduces another essential part into the construction; namely, the *tie beam* A C, (*Figure* 4,) which is laid from wall to wall, has the feet of the rafters framed into it, and binds them together. The sole office of the tie beam is to prevent the roof from pushing out the walls, though it is sometimes used for carrying the ceiling of the apartments under it, and is even made a support to the flooring; considering it as forming a part of a roof, it operates merely as a string, the strain which it withstands, tending to tear its parts asunder. It acts, therefore, with its whole integral force, and could a secure method be devised, of fastening it to the foot of the rafter, securely, a very small scantling would be sufficient for it. It may be safely subjected, when constructed of oak, to a strain of three tons: for every square inch of its section, if of fir, it will safely bear a strain of two tons for every square inch.

But there is sometimes a necessity for giving the tie beam much larger dimensions, because, in order that it may be connected with the foot of the rafter, by means of a mortise and tenon, as we have already observed. Iron straps are also frequently added. By attending to this office of the tie beam, the ingenious carpenter will be naturally directed to the most proper form of the mortise and tenon of the strap. This, however, will be considered, after we have said something on the various strains at the joints of a roof.

The large dimensions of the tie beam, allow it to be loaded with the ceilings without any risk, and even admit of floors being laid on it with moderation and caution. But when the span is great, it is very apt to bend downwards in the middle, and therefore requires a support. This support is found in the king post, B D, *Figure* 5, the office of which, is to support the tie beam. A common observer, unacquainted with the principles of carpentry, would suppose that the tie beam supported the king post, whilst in reality, it is the contrary. The king post appears to be a pillar resting on the beam, whereas it really operates as a string, and an iron rod of one sixteenth of the usual dimensions of king posts, would do just as well. The king post is sometimes mortised into the tie beam, and pins are put through the joint, which circumstances give it more the appearance of a pillar, with the roof resting on it. This may do in some cases, but the best method is to connect them by an iron strap, resembling a stirrup, which is fastened at its upper ends into the king post, and passes round the tie beam. In this way, a space is sometimes left between the end of the king post, and the upper side of the tie beam. Here the beam plainly appears to hang in the stirrup, and this method allows the beam to be restored to an exact level, when it may have sunk by the unavoidable compression, or yielding of its parts. We have described an excellent mode of forming a stirrup, in the first general division of this article.

The suspension of the tie beam is a very important part in the construction of roofs, and considerable attention is required to render it sufficiently firm. The top of the king post is cut into the form of the arch stone of a bridge, and the heads of the rafters are firmly mortised into this projecting part. These projecting parts are called joggles, and are formed by working the king post out of a much larger piece of wood, and cutting off the unnecessary part from the two sides, should this be found of insufficient strength, it is usual to add an iron plate, or strap, of three branches, which are bolted into the heads of the rafters and king post.

Having now found an excellent support for the tie beam, the next enquiry is, how the rafter is to be supported so as to be enabled to bear the covering. When a firm point of support has been obtained at the foot of the king post, the braces or struts ED, FD, should be introduced as represented at *Figure* 6; these braces or struts are put under the middle of the rafters, where they are slightly mortised, while their lower ends are firmly mortised into joggles formed on the foot of the king post.

The braces are very powerful in resisting compression, while the king post is equally so in resisting extension, and the rafters being thus reduced to half their former length, have now four times their former relative strength.

We shall next turn our attention to the construction of a flat topped roof. Let ABCD, *Figure* 7 represent the proposed roof, of which the rafters AB, CD, are equal, and BC, horizontal. Then it is very evident that these timbers will be in perfect equilibrio with one another, and therefore the roof can have no tendency to strain on one side more than the other. The tie beam AD, withstands the horizontal thrusts of the whole frame, and the rafters AB, CD, are each pressed or borne upon in their own directions, owing to their butting with the middle rafter or truss beam, BC, which lies between the rafters in a manner similar to the key stone of an arch; in which position they lean towards it, and it rests upon them. If the rafters AB, DC, are produced to meet in G, (*see figure* 8,) and a weight be laid on them equivalent to the weight of BC, and its load; this weight will be equal to the pressure of the truss beam and its load, when exerted on the two rafters AB, DC. Hence we perceive that though the common roof AGD, may be framed with a king post and braces, it will not be stronger than the roof ABCD, (while it keeps its shape) provided the truss beam is of a sufficient size to carry its own load, and to resist the compression necessarily arising from the two rafters.

We can illustrate this still more clearly, by the following plain description. Let us conceive that a roof AGD, has been constructed with the tie beam AD, and the rafters AG, GD, when this has been effected, let us next imagine that a beam BC, is framed firmly in between the rafters, which can be easily done. From hence then we infer, that the extremities of the beam BC, cannot descend, without shortening the distance BC, that is, if it should be violently compressed. It is also evident that BC, can be framed into the rafters AG, DG, in such a manner, as even to bend or force them out. When this is the case, the mutual pressure that existed between the rafters at the top, G, is destroyed; the points B, and C, being alone efficient, after which the parts GB, and GC, may be taken away without danger, and the roof may be reduced into the form ABCD, and rendered altogether as effective and strong as the former, though it may be furnished with the powerful auxiliaries of a king post and braces, because the truss beam gives a support at B, and C, of the same kind as that furnished by braces.

But after all we shall find that braces, or ties, of some kind or other, must be introduced into the flat top roof, in order to resist any addition of weight that may preponderate on one side more than the other. It is true we have asserted before that the roof was in perfect equilibrio, but it should be recollected that this assertion was made on the supposition, that equal pressures existed on each side of the roof, which is not the case in the latter supposition. In this, an addition of weight is imagined to be placed on one side, and consequently it becomes necessary to guard against the depression at one angle, and the rising of the opposite one, which it is very evident must take place. The best and most usual method is to frame the heads of the rafters into the joggles of two side posts BE, and CF, while the truss beam is mortised square into the inside of the heads. The lower ends E, and F, of the side posts are secured to the tie beam, by means of mortises and tenons, or by straps.

The introduction of these side posts gives firmness to the frame; for it must now appear evident, that the angle B, cannot descend in consequence of any inequality of load or pressure, without forcing the other angle C, to rise: but this angle cannot rise, because it is held down by the side post CF. The tie beam is also now suspended at the points E, and F, from the points B, and C.

It may be necessary, however, to observe with regard to the roof now under discussion, that the compression sustained by BC, in order to give to the rafters at B, and C, that equality of support which they would receive from well disposed braces framed into the king post of the roof AGD, is considerably greater then the compression of the braces; and that this compression adds also to the transverse strain which BC, gets from its own load; for which reasons, although this roof may be made abundantly strong, it will not be quite so strong as the roof AGD, when constructed with the same scantling.

This construction is, moreover, subject to other strains, which, though trivial in their nature, are not unworthy of notice. The principal of these strains is that which arises from the mortising of BE, into the tie beam; for the strain in its tendency to depress the angle B, presses on the tie beam at E, transversely, whilst a contrary strain operates on F, which tends to pull it outwards. This form of roof is particularly useful where room is wanted for garrets, and it may on the whole be framed of sufficient strength, without much increasing the dimensions of the timbers.

The form of roof exhibited at *Figure* 7, is free from many of these objections, to which the preceding one is liable; but it will not admit of the construction of garrets. In this roof, the two posts BE, CF, are connected together below.

All transverse strains now cease; and taking every circumstance into consideration, we feel inclined to recommend this, as the strongest mode of constructing a roof of the same width and pitch.

Not the least transverse strain exists in any of the connecting parts of this roof; and if the iron strap which unites the posts BE, CF, with the tie beam, is firmly fastened to it, and confined to one point in the

the beam by means of a large bolt going through it; then there will be five points viz. A, B, C, D, G, which will not admit of a change of position, and therefore the roof must be of a firm construction. When the dimensions of the building are so great that the pieces AB, BC, CD, may be thought too weak, in such case, notwithstanding the cross strains, braces may be added as expressed by the dotted lines in *Figure* 8. Before we conclude our description of these kinds of roofs, it may be proper to observe, that the top must not be left flat externally, but must be raised a little in the middle to carry off the rain, which may be effected by fixing pieces of timber above the strutting beam, so as to form the proper inclination.

The method of including a truss within the rafters of a pent roof, is a very considerable addition to the art of carpentry; and *Figure* 9, represents an excellent mode of constructing a roof of this kind. In order to insure its full effect, butting rafters are framed under the principal ones, abutting on joggles in the heads of the posts; for without this very necessary precaution, the strut beam is scarcely of any service. We would recommend, therefore, the form exhibited at *Figure* 10, for the construction of a trussed roof; the king post placed in it, may easily be made use of in supporting the upper part of the rafters, and also for preventing the strut beam from bending in their direction, in consequence of the great compression upon it. This mode will have the effect, likewise, of relieving the great burdens which the roofs of theatres are sometimes compelled to bear. The machinery has no other firm points to which it can be attached; and that portion of the single rafters which carries the king post being but short, it may be heavily loaded with safety.

We have now submitted to the consideration of our readers, some of the elementary principles of this important branch of carpentry. These principles will enable most practical men, with a little reflection, to proceed with confidence in becoming better acquainted with the scientific minutiæ. Without a due attention to theory, practice will rest itself vainly, on those vague notions which habit may have furnished, as to the strength and supports of timbers, and of their modes of action. A roof, or a center, framed in an intricate manner, is, no doubt, viewed by a man unacquainted with the true principles of the art, as an effectual, and ingenious construction; but his admiration would cease were he to know, that pieces of carpentry, so constructed, often fail, by reason of their being too heavily laden with timber, but more frequently by the wrong action of some useless piece, which produces strains, that operate transversely to those of other pieces, and thereby do essential injury; or that some points of the construction may be made so unnecessarily firm, as to occasion their being deserted by the rest, in the general subsiding or drawing together of the whole work. There is nothing that displays the skill and judgement of a carpenter, more than foresight, in allowing and providing for those changes of shape which must take place in every roof, in a short time after its erection. This foresight, however, cannot be acquired without science, which is necessary to perfect the art. When it is known how much a particular piece will yield to compression in one case, then science must step in to inform him what will be the effect of compression, on the same piece, in a different case. By ascertaining how much each piece is calculated to bear, and in what proportion each will yield to compression, he will be enabled so to adjust the proportions of the several parts to each other, that when all the timbers have yielded, according to the respective strains upon them, the whole construction shall be of the desired shape, and every joint in a state of firmness. Were science permitted to perform its part in these operations, the iron straps employed, would not be frequently fixed in positions, ill suited to the actual strain to which they are subject, or thrown into a state of violent twist, that tends strongly to break the strap, and to cripple the pieces, which they surround, nor would joints or mortises be seen violently straining on the tenons, or on the heels and shoulders.

When the truss is first constructed, the joints, perhaps, may be shaped properly; but when the work bears together, or settles, a change is necessarily effected in the bearing of the push; we may allude for an example of this, to the brace, in a very low pitched roof, where it not only presses with the upper part of the shoulder, but by its acting as a powerful lever, breaks it. The lower end of the brace, which at first, butted squarely, and in a firm manner on the joggle of the king post, now presses heavily with one corner, and seldom fails to splinter off on that side. All the shoulders of butting pieces should be made in the form of an arc of a circle, having the other end of the piece for its centre. This mode was recommended by Mr. Perronet, whose name has already been noticed in this work; with the respect due to his distinguished talents. Thus, in *Figure* 6, if the joint B, be an arc of a circle, having A for its centre, the sagging of the roof will not make a partial bearing at the joint; for in the sagging of the roof, the piece A B, turns round the centre A, and the counter pressure of the joggle is still directed to A, as it ought to be. But it too frequently happens, that the piece A B, bends round the centre A, for it is always very difficult to give the mortise and tenon, in this place, a true bearing; and as the rafter pushes in the direction B A, and the beam resists in the direction A, the abutment should be perpendicular to neither, but in a middle direction, and it ought also to be of a curved shape. Some may think that it might weaken the beam too much, to give it this shape in the shoulder;

shoulder; but the shoulder is commonly even with the surface of the beam, and when the bearing is on this shoulder, it causes the foot of the rafter to slide along the beam, till the heel of the tenon bears against the outer end of the mortise. This abutment is generally pointed a little outwards, below, to make it more secure from starting. Now when the roof settles, the shoulder bears at the inner end of the mortise, and rises at the outer, the consequence of which is, that the tenon takes hold of the wood beyond it, and either tears it out, or is itself broken. This joint, therefore, ought not to be trusted to the strength of the mortise and tenon, but should be secured by an iron strap, lying obliquely to the beam, to which it is fastened, by a large bolt running quite through, when it embraces the foot of the rafter. There are many defects in the forms of straps; in general, they are not made sufficiently oblique, and thereby they never fail to cripple the rafter at the point. But this may be prevented by making the strap very long, and very oblique, by forming the stirrup part, square with its length, and cutting a notch in the foot of the rafter to receive it. By proceeding in this manner, the rafter cannot be crippled, because it will rise along with the strap, and turn round the bolt at its inner end as a centre. As the ultimate, or aggregate strain of the whole roof is exerted on this joint, and its situation will not allow the necessary excavation for making a good mortise and tenon; it has been considered necessary to be particular in describing this joint.

The construction of the straps, which embrace the middle of the rafter, and connect it with the post or truss below it, also demands considerable attention. The change of shape, produced by the sagging of the roof, must be well weighed, and care must be taken to place the strap in such a manner, as to be enabled to yield to the change, by turning round its bolt, but still not so as to become loose, and far less to form a fulcrum for any thing which may act as a lever.

Having frequently spoken in the foregoing pages, of the strains, or thrusts, to which timbers in general are exposed; this part of our article would be incomplete, if we did not point out some methods by which the practical carpenter may arrive at the necessary calculations, in this interesting part of his profession. In adverting to these, we shall not entangle him in a labyrinth of deep mathematical disquisitions, but confine ourselves, for the present, to such operations as may be learnt by any man who is commonly versed in arithmetic, and practical geometry. A full enquiry into this part of the subject will be reserved for the latter department of the article Carpentry.

If, in the first place, it should be required to determine the horizontal thrust acting on the tie beam A D, of *Figure* 8, the effect of the thrust will prove to be the same as if the weight of the whole roof were laid at G, on the rafters GA, and GD. Let the vertical line GH, be drawn, and let the weight of the whole roof supported by the single frame ABCD, be calculated, including the weight also of the pieces AB, BC, CD, BE, CF, after which take such a number of tons, pounds, &c. as may be sufficient to denote the weight from any scale of equal parts, set the same from G to H, draw HK, HL, parallel to GD, GA, and draw the line KL, which will be horizontal when the two sides of the roof have the same inclination. Then if ML, be measured on the same scale, it will give the horizontal strength by which the strength of the tie beam is to be regulated. GL, will give the thrust which tends to crush the strut beam BC.

In a similar manner in finding the strain of the king post, *Figure* 6, each brace may be considered as pressed by one half of the weight of the roofing laid on BA, or BC, and consequently that part of this pressure which might otherwise have proved injurious to the construction, is diminished in the proportion of BA, to DA; but, as this is to be resisted by the brace f E, which acts in the direction f E, f e must be drawn at right angles, to E e, and must be considered as the strength increased in the proportion of E e, to E f.

Having thus obtained in tons, pounds, or other convenient measures, the strains required to be balanced at f, by the cohesion of the king post, the measures must be taken from the scale of equal parts, and laid off in the directions of the braces to G, and H, and then the parallelogram G f H K, being compleated, we can measure f K, on the same scale of equal parts, which will represent the actual strain on the king post.

We can now very readily examine the strength of a truss upon this principle; viz. that every square inch of oak will bear at an average 70·00 pounds, compressing or stretching it, and may be safely loaded with 3500 for any length of time; and that a square inch of fir will in like manner bear securely 2500. And because straps are used to resist some of these strains, a square inch of well wrought iron may be safely strained with 50,000lbs. But we should always recollect that timber may be depended on more than iron; for the faults and defects of the former are more easily perceived, because it gives us warning of its failure, by yielding sensibly before it breaks, whereas this is not the case with iron, because much of its service depends on the honesty of the smith.

By proceeding in a similar manner, the strength of any roof may be examined.

We shall now proceed to lay before our readers a few designs of roofs; some intended for the simple cottage, and others for grand and magnificent structures.

Figure 11, is intended for a building, whose span is from 20 to 30 feet.

Figure

Figure 12, is a design of a truss for a roof, whose span is from 20 to 35 feet; the purlines are notched upon the principal rafters.

Figure 13, is another design for a roof, whose span is from 20 to 35 feet; it may be made use of to form the segment finish of a dome.

Figure 14, is a design for a roof, in which the purlines are framed into the principal rafters, so that the common rafters may finish fair with the principals.

Figure 15, is the form of a roof in which are introduced two queen posts instead of a king post; the space between the queen post is intended for a passage, or any other conveniency that may often times be required in a roof.

Figure 16, is a plan for a curb roof, having a door in the middle of the partition.

In the roof delineated at *Figure* 17, it will be perceived that one third part of its height is diminished, while the truss is made exceedingly firm with little wood, and labour. On the head of the central king post, a gutter plate is let in, which bears the inside rafters, and is so adapted, that it may be supported at pleasure between one truss and the other.

The roof exhibited at *Figure* 18, is called an M roof; it is suitable for a large span, or when there is no wall between to support the tie beam.—When this is the case, we should recommend *Figure* 19, as a very useful form.

Figures 20, and 21, are designs for church roofs; these designs are susceptible of many modifications.

The roof delineated at *Figure* 22, is the roof of the theatre of the university of Oxford, and designed by the celebrated Sir. Christopher Wren; it is considered a very ingenious and singular construction. The span between the walls is 75 feet; the middle part is almost unchangeable in its form, and, from this circumstance, it does not distribute the horizontal thrust with the same regularity as the usual construction. The horizontal thrust on the tie beam is about twice the weight of the roof, and is withstood by an iron strap below the beam, which stretches the whole width of the building, forming a part of the ornament of the ceilings.

Having now spoken of several excellent kinds of roofs, we shall proceed next to consider the methods whereby the several parts of a roof are connected together.

In the first general division of this article, we have spoken of various methods of joining timber, many of which may be applied to the construction of roofs; we shall, therefore, pass on to consider a mode for finding the length and backing of a hip.

The first, and most simple problem, that naturally presents itself to our consideration in this case, is when the building forms a perfect geometrical square. Let this square be A B C D, as shewn in *Figure* 1, *Plate* 12.

Join the diagonal points, A B, C D; then it is well known, from the elementary principles of geometry, that these diagonals will bisect each other at right angles in E; lay off from E, on either of the diagonals, the part E F, equal to the height of the roof; join A F, and it will shew the lengths of each of the hips as required.

For if the triangle A E F, be supposed to revolve round the line A E, into a position perpendicular to the plane of the plan A B C D, and lines be drawn from F, to the several points B C D, then it is evident that the several lines A F, B F, C F, and D F, are all equal and therefore the preceding mode of construction is correct.

Similarly for *Figure* 2, which is the plan of a roof in the form of a parallelogram, having a ridge in the middle.

Lay off on the ridge line the part C D, equal to one half of the width of the building; join A D, B D, and they will form the angle A D B, equal to a right angle, this being effected, produce A D, to F, so that D F, may be of a length equal to the height of the roof; join B F, and it will be the length of the hip rafter, for either side of the roof.

Figure 3, next presents itself, being the plan of a rectangular roof, which is required to be framed with four hips, and all to meet over E, the centre of the plan.

The centre of the plan is evidently found by the intersection of the diagonals A C, B D, in the point E; from this point, erect the perpendicular E F, equal to the designed height of the roof, and join A F, or C F, and either of these will express the length of each of the required hips. If the plan of the roof had been a triangle, and the hips required to meet over its centre, the operation would be exactly the same. Admit next, that the plan of a building be a trapezoid, and it is required to determine the several lengths of the hip rafters of a roof, to cover the same.

Let A B C D, represent the given plan, and bisect A B, C D, in the points E F; join the point E F, and on A B, C D, describe semicircles to intersect E F, in the points G H; join G A, G B, G C, and G D, and produce each of these lines to the points I, K, L, M, so that G I, G K, H L, and H M, may be each equal to the height of the intended roof; join K A, I B, L C, and M D, which will be the lengths of the several hip rafters.

Should the plan of a building be any regular polygon, whatsoever, the length of the hip may always be found by joining two of the opposite angular points, and erecting a perpendicular from their intersection, equal to the intended height of the roof, and then this point joined with the angular point of the figure, opposite to the line, will give the length of the required hip.

Here, first turning back to *Figure* I, draw any line, H G, at right angles to either of the lines, A B,

C D, intersecting it in the point K; draw K L, perpendicularly to A F; then with K, as a centre, and distance K L, describe a circle to intersect A E, in I, join I G, and I H, then will the angle G I H, be the backing of the hip. It will be very readily perceived, that a mould may be formed, corresponding to the angle G I H, for the more convenient working of the hip; this, however, is not the very best method, for by demitting G M, perpendicularly to C D, and forming a mould to correspond with the angle M G I, the hip may be backed, by applying the mould to one of its parallel sides. These two moulds are represented in the diagram, by the shaded parts.

The backing of the hip in *Figure* 2, is precisely the same as the preceding.

In *Figure* 3, the backing will be found in the same manner as the others above, only this roof will require two different bevels, each of the parallel sides of the hips is shewn at L; when the hips are to be mitred together, M and N, will shew the bevels for each half, so that when put together, they may form the proper backing. The backing and mitring of the hips, in *Figure* 4, is found by the method described for *Figures* 1 and 2.

We will now consider the mode of finding the proper bevels of the end of a purline, so as to make it fit against the hip rafter.

To effect this, let us first imagine, that A B, represents the width of a square building, with the roof framed with hip rafters, the first tie beam of which is placed parallel to the end wall, and at a distance from it, equal to half the width of the building; hence, take B C, which is equal to one half of A B, and through the points A and C, draw A D, C D, respectively parallel to B C, B A, so as they may meet each other in D, then bisect D C, in E, and join E B; draw also E F, perpendicular to C D, and equal to the intended height of the roof, and join F C, which will represent the length of the common rafter.

Now as the purlines are square, and usually placed at right angles with the rafter, assume the point G, in F C, and construct the rectangular figure G m n o, equal to the section of the purline, or any proportionable reduction thereof. Produce G m, to meet DC, in H, and through G draw KGL parallel to E C, and make G K, G L, and G M, each equal to G H, next let H N, G R, and M O, be drawn parallel to B C, and so as to intersect B E, in the points N, R, O; draw N P, and O Q, parallel to E C, so as to intersect respectively, K P, and L Q, drawn parallel to B C, in the points P, Q: and then, join P R, R Q, when the angles P R G, G R Q, will represent what is usually termed, the down, and side bevels of the purline. A mould may now be formed from these angles, in order to cut the ends of the several purlines of the roof, it being evident, that when the building is square, each end of the purline that meets the hip rafter, is precisely the same.

In order to find the bevels of a jack rafter against the hip, it may be observed that the angle E F C, is its down bevel, as represented by the mould in the figure, and if R S, be drawn parallel to A B, and the stock of the side bevel of the purline be made to coincide with R S, the side bevel will be shewn.

The laying out of an irregular roof in ledgement, must be next considered.

Let A B C D, represent the plan of the intended roof, having the positions of the beams delineated on it. At the points G, H, I, where the ridge line intersects the beams, erect each of the perpendiculars I K, H L, and G M, equal to the intended height of the roof, and join the points K N, KO, LP, LQ, and M R, M S, which will be the lengths of the several principal rafters; after this, join also A I, BI, C G, and D G, when the lengths of the several hip rafters A T, B U, GV, and D W, may be found by the method before laid down for that purpose. Next on A B, construct the triangle A a B, in such a manner that A a, B a, may be equal respectively to A T, B U; after which, on C D, construct another triangle, C b D, having C b = C V, and D b = D W, then these triangles will represent the ends in ledgement. Again, on the line D S, construct the triangle D C, so as that D c, may be equal to D W, and S c, may be equal to S M. In a similar manner, construct the triangle B d O, having B d = B u, and O d = O K, join d c, and lay off d e, equal to H I; then join Q e, which is equal to the principal rafter Q L, and lastly, after having drawn in the purlines at discretion, the ledgement of that side of the roof will be compleated, and the other side may be performed in like manner.

Our observations will next be directed to the roofs, placed on round, and polygonal buildings, such as domes, cupolas, and the like. The greatest difficulty in the formation of these kinds of roofs, arises from the mode of framing. It is true, that whatever form of making a truss may be deemed preferable in a square building, it must have the same constituent parts as the truss used in a round one; the only difficulty being in modifying the shape, and connecting the parts at the top. It is evident that some of these parts must be discontinued before they reach a certain length, and it is also equally evident, that they ought to be cut short alternately, yet care must be always taken to leave sufficient strength, and that the parts may stand equally thick as at their first springing from the base of the dome, by which means the length of the purlines reaching from truss to truss, will never be too much. Nothing, in fact, can be more easy to construct than a round building, continually diminishing until it reaches an apex, such, for instance,

stance, as a spire steeple. Daily practice amongst builders confirms this observation, for how often do we perceive spires and steeples constructed without centers, and without scaffolding? Gross indeed, would be the errors in constructing them, if much danger were to be apprehended of their falling from a want of equilibrium. In like manner, a dome of carpentry, whatever may be its shape or construction, can hardly fall, unless some of its parts should fly out at the bottom, and this can be easily prevented by fixing an iron hoop around the bottom, or connecting straps with the joining of the trusses and purlines. Architectural beauty requires that a dome should spring almost perpendicularly from the wall, and if we admit this, it may be readily perceived that the thrust exerted to force out the walls is very small, only it is necessary to guard against the operation of this thrust, and that is, where the tangent inclines about 40 or 50 degrees to the horizon, at which place it will be proper to make a course of firm horizontal joinings.

We are of opinion that domes of carpentry may be raised of great extent, as sufficient room appears to offer itself for improving this very interesting branch. The Halle du Bled, (which was constructed by an ingenious carpenter named Molineaux), is 200 feet in diameter, although it be not more than a foot in thickness, and yet it appears to possess abundant strength. Molineaux, being convinced by his mechanical experience, that a very thin shell of timber might be constructed so as to be nearly in equilibrio, and that when hooped or firmly connected horizontally, it would have all the requisite stiffness, presented his ingenious project to the magistrates of Paris, who, having doubts of its practicability, submitted the plan to the consideration of the members of the Academy of sciences. Such of these as were competent to the task, investigated the principles of the intended construction, and were immediately struck with its propriety, expressing their astonishment, that a thing which appeared to be so very obvious, should have escaped the attention of preceding carpenters. The academy, accordingly, presented a very favourable report of the plan, which was immediately carried into execution, and being soon compleated, it now stands as a monument, a proof of the inventive genius of Molineaux, and is justly considered one of the most curious exhibitions in Paris. The construction of this dome is very simple; the circular ribs of which it is composed, consist of planks nine feet long, thirteen inches wide, and three inches thick, and each rib consists of three of these planks bolted together in such a manner, that two joints are contrived to meet. A rib is begun, for instance, with a plank of three feet long, standing between one of six and another of nine feet; and this is continued to the head of it. At various distances these ribs are connected, horizontally, by purlines and iron straps, which act as so many hoops to the whole construction. When the work arrived at such a height, that the interval between the ribs formed two thirds of the original distance, every third rib was discontinued, and the space between was left open and glazed. When the work had been carried so much higher, that the distance of the ribs formed one third of the original distance, every second rib, (now consisting of two ribs very near each other,) was in like manner discontinued, and the open space was glazed. At a small distance above this, a circular ring of timber was framed into the ribs, by which means a wide opening was made in the middle; over which is a glazed canopy, with an opening between it and the dome to allow the heated air to escape. Every beholder is struck with the grandeur and the simplicity of this construction, and every unprejudiced mind cannot fail to confess, even from the idea we have endeavoured to give, that it must form a beautiful and magnificent object.

In the construction of some domes one great difficulty is to be overcome, and that is, when they are unequally loaded by having to support a heavy lanthorn, or cupola, in the middle. In such a case, if the dome were only a mere shell, it must be crushed in at the top, or the force of the wind operating on the cupola, might remove it, and its supporter out of their place.

The dome of St. Paul's cathedral is a model of propriety in this particular method of construction, and much valuable information may be derived from considering the principles on which it was erected. These are shewn in *Figure* 23, of *Plate* 11, where ABCCBA, represents the dome turned over with bricks, two feet in length, which were made on purpose.

E F G G F E exhibit a cone of bricks, one foot six inches in thickness, and visible through the opening C C. This cone, aided by the timber work of the dome, supports a cupola constructed of Portland stone, nearly sixty-four feet in height, and twenty one feet in diameter. The timber work Z Z, is ingeniously tyed together with iron cramps, run with lead into the stones M, N, O, P, and then bolted through the hammer beams H H, I I, K K, and L L. From these principles it may be perceived, that the timber work derives considerable support from the brick cone.

The construction of this dome affords a strong proof of the profundity of Sir Christopher Wren's Mathematical judgement, and his unrivalled excellence in constructive carpentry.

Figure 24, represents a dome raised over the Register office at Edinburgh, by Messrs. James and Robert Adam. In this instance the construction of this dome appears agreeable to mechanical principles, and consequently is deserving of attention, particularly when it is considered that the span is 50 feet clear, and the thickness only $4\frac{1}{2}$ feet.

The

The principle of a Norman roof is ingenious and simple. The rafters all butt on joggle king posts A F, B G, C H, &c. (as in *Figure* 25) and then braces or ties are disposed in the intervals. The ties H B, H D, are in a state of extension, while the king post C H, is compressed by them. Towards the walls on each side, as for instance, between B and F, F and L, they act as braces, and are themselves compressed. The ends of these posts were generally ornamented with knots of flowers and other devices, and even the whole texture of the truss was exhibited and dressed out.

Short timbers may be employed in these kinds of constructions, and this very circumstance imparts additional strength to the truss; for the reason that the angle which the brace or tie makes with the rafter is more open. All thrust, likewise, may be removed from the walls, which demands attention. If the pieces A F, B F, L F, were to be removed, then the remaining diagonal pieces, will act as ties, and the pieces directed to the centre, will act as struts.

The application of this principle to a flat roof, or to a floor, will be productive of advantages similar to those which we have before stated. For instance, a floor, such as a b c, having the joint in two pieces a b, b c, with a strut b d, and two ties, will require a much greater weight to break it, than if it had been a continued joist, like a c, of the same dimensions. Moreover a piece of timber operating as a tie, is much stronger than the same piece if applied as a strut; since in the latter situation it is exposed to bending, and when bent is much less able to withstand a very great strain. It must be ackonwledged, however, that this advantage is balanced by the great inferiority in point of strength of the joints. The joint of a tie depends wholly on the pins; for which reason, ties are never used in heavy works without strapping the joints with iron. In the roofs we are describing, the diagonal pieces of the middle part only, act entirely as ties, while those towards the sides act as struts or braces. Indeed they are seldom of such simple construction as we have pointed out, and are more generally constructed like the sketch delineated in *Figure* 30, where there are two sets of rafters A B, a b, and the angles are filled up with thin planks, which circumstances are productive of strength and stiffness. They have likewise a double set of purlines for connecting the different trusses. After the roof has been thus divided into squares, other purlines run between the middle point E, of the rafters, the rafter at E, being supported by a check placed between it and the under rafter. The middle point of each square of the roof is supported and stiffened by four braces, one of which springs from e, having its opposite braces springing from the similar part of the adjoining truss. The other two braces rise from the middle points of the lower purlines, which proceed horizontally from a and b, to the next truss, and are supported by planks in the same manner as the rafters. By this contrivance, the whole construction is rendered very stiff and strong.

The figure delineated at *Fig*. 26, is intended to represent a timber spire, whose plan is an octagon, and whose height is equal to eight times the length of one of its sides, as is exhibited in the drawing. It will not be necessary, in all cases, to limit the height of a spire to eight times the length of one side of its base, since it may be made to exceed nine or even ten times that length; and spires constructed in that manner will have all the elegance of well proportioned columns.

Fig. 27, 28, 29, and 30, represent other plans of spires, which merit the attention of those who are desirous of improving themselves in their professional knowledge.

TRUSSING GIRDERS.

Fig. 2. and 3, of *Plate* 7 of Carpentry, shew the most approved method of trussing girders.

Fig. 4 represents an horizontal section of *Fig*. 3.

Fig. 5 exhibits a section of the butment formed by cutting across a b, in A.

Fig. 6 and 7, represent the two sides of the king-bolt, at C, in *Fig*. 2, which is made with a wedge-way upon the top, so that it may force out the trusses upon the butments.

TO TIGHTEN THE GIRDERS.

The trusses should be let in close to the sides of the girder, about an inch and a half on each side, and the head of the king bolt ought to be greased, so as to permit its sliding freely by the ends of the trusses; after screwing the girder close, sideways, the nut of the king bolt may be turned, while another person strikes the head of the king, at C, with a mallet, which will cause it to start every time it is struck, and produce greater ease at every revolution of the nut, by which means the girder may be brought to any degree of camber that may be necessary. This, however, is not generally more than an inch in twenty feet.

Fig. 7, 8, 9, 10 and 11, represent designs of trussed partitions.

SOFFITS.

A soffit is defined, by theoretical carpenters, to be the covering of any surface whatever with wood arranged on a plane.

In a straight wall which flues equally all round, it is requisite to describe a soffit with a circular head. On A B, or CD, being the sides of the plan ABCD, *Fig*. 1, *Plate* 7, describe semicircles, and produce AC, and BD, to meet in E; then with E as a centre and the distances EA, EC, describe the circular arcs E F, and E G; next divide the circumference of either of the semicircles into any convenient number of equal parts, (say ten,) and then laying off a similar number of divisions either from A or C, to F or G, join F E, and the required soffit will be compleated.

Next

Next, in a circular wall which flues equally all round, it is required to describe a soffit with a circular head.

Let A B C D, as in *Figure* 2, represent the given plan, join A B, and having described on it the semicircle A H B; then lay out the soffit in the same manner as before directed. From the several points of division 1, 2, 3, 4, (made use of to effect the preceding) draw the perpendicular ordinates 11, 22, 33, 44; join F 1, F 2, F 3, and F 4, so as to intersect the curve line A B, of the plan A B C D, in the points a, b, c, d; through these points draw lines parallel to A B, in order to intersect A F, in m, n, o, p; next with centre F, and distances Fm, Fn, Fo, and Fp, describe circular arcs so as to intersect respectively F 1, F 2, F 3, and F 4, in the points a, b, c, d; then by these points the half of one edge of the soffit is found, from which the other half may be very readily pricked. The reverse edge is found in the same manner.

Again, let it be required to stretch out a soffit, when a door or window, having a semicircular head, cuts into a straight wall, in an oblique direction.

In the figure delineated at *Figure* 3, let A B C D, represent the given plan; and at the point B, erect the perpendicular B E, so as to intersect D A, produced in E, and on B E, describe a semicircle; let the circumference of this be divided into any number of equal parts, (say ten) and let the ordinates be drawn from the several points of division across the plan A B C D: next produce B E, indefinitely, and on it, lay off the several divisions 1, 2, 3, 4, &c. of the semicircle, then, when the ordinates have been all drawn across, and traced off from the plan as the figures and letters direct, the required soffit will be compleated.

For more compleat information on this subject we refer to Nicholson's "*Carpenter's new guide.*"

NICHES,

Are hollows sunk into a wall for the reception of statues having their bottoms planned according to any segment of a circle or an ellipsis, and their tops terminating or formed into a kind of canopy.

Niches are sometimes made square, but they are then entirely destitute of elegance and beauty.

Let us suppose, in the first place, the plan of a niche to form the segment of a circle, and its head a semicircle, to describe the ribs for its top,

Let A B C, *Figure* 4, *Plate* 7, *of Carpentry*, represent the sill, and a, b, c, d, e, f, the front rib; then it is evident that the head of the niche forms one half part of the segment of a sphere, the base of which portion is the semicircle a, b, c, d, e, f.

Hence, then, any one who is conversant with the elementary principles of spherics, may easily perceive, that each of the required ribs of the niche will be of the same length, and possess the same degree of curvature as A B, the one half of the sill of the niche; and therefore by it, the several ribs can be readily obtained. We deduce, therefore, from the preceding, that though the sill of the niche and its front rib also, should form a semicircle, yet the ribs could have been obtained in the same manner, by merely applying one half of the sill.

Lastly, having given the plan and elevation of an elliptic niche, it is required to find the sweep of the ribs.

In *Figure* 5, describe every rib with a trammel, or by means of a string and two points, as elucidated in the article geometry in the introduction of this work; by taking the distance on the plan from the base of each rib to the center for the extent of each, or one of its axis, and the height of each rib to the height of the top of the niche for the other, the true sweep of each rib will be acquired.

It will not be necessary to form any moulds, in order to back the ribs of the niche, since the ribs themselves will perform this office; as there will be two ribs of each kind, take the small distances 1 e, 2 d, from the plan at B, and apply them to the bottom of the ribs D, and E, from d, to 2, and e, to 1; then the backing may be drawn off by the other corresponding rib, or with a trammel as is exhibited at E, by moving the centre of the trammel towards e, upon the line e c, from the centre c, equal to the distance 1 e, letting the trammel rod remain the same as when the inside of the curve was described.

Let one of the common ribs of a cove bracket be given to find the angle bracket for a square or rectangular room, *Figure* 6. Let A, be the common bracket and b c, its base; draw b a, perpendicular and equal to b c, join a c, which will be the place of the mitre, let any number of ordinates be taken in A, and perpendicular to b c, its base; and let them be continued so as to meet the mitre line a c; draw the ordinates of B, at right angles with it; then by pricking the bracket at B, from A, as may be readily seen by the figures, the form of the required angle rib will be shewn. The same rule will do for any other bracket whatever. It should be observed, however, that the angle rib must be backed, either externally or internally, according to the angle of the room.

GROINS.

Groins are the angular curves made by the mutual intersections of semi-cylinders or arches, and may be considered as either regular, or irregular. A regular groin is properly so called when the intersecting arches, whether semicircular, or semi-elliptical, are of similar diameters and heights; an irregular groin, is properly so called where one of the arches is semicircular, and the other is semi-elliptical; thus *Figure* 1, *Plate* 8, presents the plan of an irregular brick groin, whose body arch A, forms a semicircle, and whose intersecting or side arches B, B, are semi-ellipsis.

Figure 2, exhibits a perspective representation of a regular brick groin, the arches of which are semicircular, of the same diameter, and intersect each

other

other at right angles; and, since any oblique section of a cylinder produces a regular elliptic curve, it is evident that the angular ribs of such groins will be semi-ellipses, having their transverse axis horizontal, and their semi-conjugate vertical. This also will be the case when the intersecting or side arches, as at B, B, *Figure* 1, are elliptical, for as 1, 2, 3, 4, evidently form the base lines of such sections, it is easy to conceive that their ordinates will coincide with those of the body arch A, which, from being a semicircle, consequently produces an elliptic arch, (as is represented at *Figure* 3,) with its horizontal axis equal to 1, 2, or 3, 4, and its vertical to A b, (*Figure* 1). It may now be perceived that the intersecting arches B, B, are formed by the erection of what workmen call the jack ribs, a perspective view of which is exhibited at *Figure* 3, where 2, 3, 4, shew the manner of their being fixed on the body arch A, after it has been boarded over. To keep these jack ribs true, and in a right line at the top, good workmen place a transverse board upon the crown of the arch, (as shewn in *Figure* 3,) fixing it sufficiently low to receive the thickness of the covering, that the body and intersecting arches may be perfectly even when the whole is covered with boards, as in *Figure* 2, which represents the state of the groin when ready for turning the brick work over the arches. Let it therefore be observed that the body arch A, *Figure* 3, must be entirely covered, before the erection of the jack ribs, whose seat on the body arch, and their several heights, as shewn at C, 2, 3, 4, *Figure* 3, may be readily found by inspecting the figure.

It is next required to find the mould for the jack ribs. Let a b c, *Figure* 4, be the body arch, and a d e, the intersecting elliptic arch; draw similar ordinates to both arches, as 1, 2, 3, &c. make them intersect each other, and produce them each way at pleasure. Make g h, equal to the circumference or girt of a b, and g k, equal to the girt of a 1 2 3 d. Divide g h, and g k, into four equal parts, (because the quadrantal arcs of the semicircle and semi-ellipse were so divided; then draw through each division perpendicular lines, so as to cut at right angles the ordinates which were drawn out at pleasure; and if curves be drawn through the points of their intersections 5, 6, 7, 8, 9, 10, they will produce correct moulds, by which the mitering of each arch, or their respective coverings may be described. Suppose it were required to mark a line on the body arch at *Figure* 3, contrived so as to touch the extremity of each jack rib at the base; in such case the mould 5, 6, 7, *Figure* 4, must be taken, and if this be made of thin pliable wood, the end h, is fixed to the crown of the body arch at h, *Figure* 3, when after securing it to that point, the other end 5, is pressed, and with a pencil the required curve is traced out. After a similar manner the other mould, 8, 9, 10, may be applied to the intersections of the elliptic arch, and if we suppose it to be covered, as is shewn at *Figure* 2, and the arch to be drawn back and separated from the body, the mould 8, 9, 10, bent over the boards, will be found to coincide with their ends, provided the arches are of the same dimensions, which is not the case, however, in this example, although in theory the principles are entirely the same.

In fixing the ribs of the body arch, at *Figure* 2, C d are strong wooden posts, and i i are the ends of beams extending the whole length of the groin, and supported by posts under each rib. The girders of each rib lie between, which are omitted, however, at e, in order to give a clear view, of the internal parts of the arch. These long beams also act on the principle of wedges, as may be seen at e; so that when the brick-work is properly set, they are eased gradually, and the wooden ribs, beams, and posts, are easily struck and cleared away.

Let us next consider the plan of an ascending or descending groin, and also of the side arches, in order to find the intersection of the angles, and the moulds for describing the curvature of the intersecting arches, the general principle of which problem, is the same as that of the preceding. To project the present figure, let one quarter of the body rib B, be divided into four equal parts, as at 1, 2, 3, *Figure* 5, and let the lines be drawn from these points, to the perpendiculars 4, 5. and continued round to 4, 6; then let the lines of descent 48, 67, &c. be drawn, and make C, equal to one of the given side arches in the descent, though the introduction of more would make no difference. From the several points I, 2, 3, &c. of the arch C, where the lines of descent cut the circumference of C, draw lines perpendicular to the lines of descent, and continue them at pleasure. Again, from the same points 1, 2, 3, &c. at C, draw lines perpendicular to the lines of descent, and let them also be produced at pleasure. Again, from the same points 1, 2, 3, &c. at C, draw lines perpendicular to the sides of the plan A, and from the points in B, repeat the same operation, when the intersection of these lines will give the curves of the arches on the plan, as will appear on inspecting the diagram. When lines have been drawn from C, perpendicular to the lines of descent, measure the girt of the quarter arch at B, and transfer it to the center line at C, as 4, a, b, c, d, through which divisions, draw lines parallel to the descent, when their intersections will produce the required curve for the mould, which is to be applied in the same manner as pointed out in the foregoing example.

The figure delineated at *Figure* 6, represents a groin, whose intersecting, or side arch B, is Gothic and under pitch, that is, it has its perpendicular height less than the height of the body arch A which forms a semi-circle. From B, the intersecting arch, project a line from 1, round to 1, at the body

body arch A, and from 1, let fall a perpendicular to s, the centre of the side arch, at A, draw the cord line 3, 4, 5, and let it be divided into four equal parts; draw lines also from 2, through each division, and produce them until they cut the arch, then from 1, draw lines through the points on the arch to the perpendicular o p: take o p, and place it on the side arch B, so as to create the same divisions as at A, then let the cords of the side arch be drawn, and divided into four equal parts, and proceed as before at A; finally, draw lines from 1, to o p, so as to intersect the lines which issue from the centre 2, and the intersecting points will give the curve of the side rib D. When the plan line p s, of the angular rib is drawn, let s q, be drawn perpendicular to it, then take the height of the intersecting arch 1, 2, and place it to 9; then let the cord line p q, be drawn, and proceed with the rest as before, and the angular rib E, will be produced as required. The same operation may be performed by ordinates in the common way, as is represented on the opposite side of the figure.

This groin is intended for plaster, and consequently very great exactness is required in the formation of the angular ribs, and the utmost correctness is necessary also on the under side, to produce regularity and smoothness in the ceiling.

Figure 7, represents the plan of another plaster groin, whose body arch A, forms a semi-ellipsis, and whose intersecting ones B, B, are semi-circular; D, is the angular rib, described by ordinates, as appears by the corresponding numerals, which method we have already described. The plan exhibited at C, shews the jack and angular ribs, as shewn in the preceding examples.

The next object of the readers attention is the plan of a curved groin, which may be applied, either to brick work or plaster, though in the present instance, it will be confined to the latter.

Let a, b, c, d, *Figure* 8, be considered as the plan of the body arch, and if this plan be continued round until it form an entire circle, nothing more would be requisite than to repeat what is exhibited in the figure before us. Let A, A, represent the body arches, and B, B, the intersecting arches, when in order to find the curvature of the angular ribs, adopt the following method. Let the base of the arch A, be divided into equal parts, from which points, raise perpendiculars to p, q, r, then produce the sides of the plan until they meet at S, and divide the curve a, b, into 8 equal parts, from which points of division, draw right lines to the centre s, let these be intersected by describing the several curves, by the centre s, from the several divisions of the base of the body arch A; through the points thus found draw the several curve lines, and they will form, when they are placed perpendicularly on their base, the correct plan of the angular ribs.

The vertical curve of the ribs, is found in the following manner; draw d, g, and make it equal in length to the curve line C d, then lay the girt of the curve line C a, from A to h, and divide it into four equal parts. Take the ordinates from A, and let them be transferred to their corresponding places in E, and D, when the curve, passing through these points, will be the vertical arch of the angular ribs. It must be observed, that when E and D, are fixed on the plan, they are supposed capable of being bent so as to coincide with the angular curves on the plan, otherwise they must be shaped to that curve, out of timber of a suitable thickness; and for this reason the intersecting arches divide the curves of their plan into the same number of equal parts, as before, which is exemplified at e f B, where e f, is made equal to the length of a b, on the curve, and i s k, is rendered equal to the curve c d, and when their ordinates are drawn, all that remains, is to transfer the several corresponding ones from A, by which the elliptic curves of the intersecting arches are found, and when placed on their plan, they must be made to coincide with their curved plans a b, and c d, by the same means as were used for obtaining the angular ribs. The jack ribs of the body arches A, A, will be straight on their plan, as at w, and must be placed in the direction of the radials, from the centre s. The jack ribs of the intersecting arches, must be curved on the plan, in conformity to their distance from the centre s, as represented by n.

Figure 9 exhibits the plan of a cylindro-cylindric, or Welsh groin, or one under pitch, the body and intersecting arches of which are composed of semicircles or of similar segments, whose intersections meet on a curve plane, and therefore their plan will be a curve, as in the foregoing example. When the intersecting arch B, has been divided into any number of equal parts, let lines be drawn at pleasure, perpendicular to its base. From the points 1, 2, 3, 4, let lines be carried round to the body arch A, as at 1, 2, 3, 4, from whence, draw lines perpendicular to the base line of A, and where these intersect at 1, 2, 3, 4, draw a curve line, which will give the plan of the angular rib of the arch. The rib itself at D, may be found as usual, and to this the numerals afford a direction. To find the mould necessary to describe the curvature of the intersecting arches when laid on the body arch A, take the girt of the angular rib D, in the inside, at 1, 2, 3, 4, and draw a right line at E; then take the ordinates from the cord line of the plan of the angular rib, and place them respectively at 1, 2, 3, 4, which will produce the required mould. The angular rib in this figure will be curved both ways, similar to the shape of the circular groin, which has been before described, the same means of describing the former may be made use of, as were adopted with respect to the latter.

Figure 10, displays the method of describing the ribs of a groin over stairs upon a circular plan, in which

which the body rib is supposed to be given. Let the tread of as many steps be taken as may be thought convenient, and of corresponding height, which lay down at F; when draw the plan of the angles as in the other groins; then take the length round the middle of the steps at E, and lay it from a to b, at F; make d e perpendicular to b c, at B equal to d e at F; draw the hypothenuse a c, with the perpendiculars, from d c up to B, and mark B from A, as the figures direct; when B will be the mould to stand over a b; at the angles draw the cords a 4, and 4 m; let a 9, 4 h, be perpendicular to them, and each be equal to half the height d e, at B or F; next draw the hypothenuses g 4, and h m, and the perpendicular ordinates, from the cords, through the intersection of the other lines that meet at the angles; after which trace the moulds D, and c, from the given rib A, and the moulds will be formed for the angle, or intersecting ribs. The angle ribs D, and C, are shewn in contrary positions, with a view to avoid confusion, through an intermixture of their lines. (*Nicholson's Carpenter's New Guide, page 30.*)

The several parts of constructive carpentry, having now been described, in this second division we shall proceed to compleat our account, by enumerating the various authors who have written on the subject, and giving some extracts from their several works.

Among the Italians Serlio, and Andrew Palladio, have been particularly eminent for their designs in carpentry. The first book of the latter was translated by Godfrey Richards, an Englishman, at the end of which he gave some remarks of his own, which well merit attention. This translation, with the remarks, attained a third edition in 1676. Among original English works, have been Moxon's *Mechanical Exercise*, a second edition of which appeared in 1693; Halfpenny's *Art of sound building*, printed in 1725; *The Carpenters Companion*, by Smith, published in 1733; *Ancient masonry*, by Batty Langley, which appeared in the same year; *The British Carpenter*, by Francis Price, printed in 1765, which has attained a fifth edition; and *The Gentlemen's and Builder's Repository*, by Edward Hoppus, printed in 1738; *The Builder's Complete Assistant*, by Batty Langley, published in the same year; *The Builder's and Workman's Treasury*, by the same author, printed in 1741; and also *The Builder's Jewel*, by the same author; *The London Art of Building*, by William Salmon, a third edition of which appeared in 1748; *The British Architect*, by Abraham Swan, a second edition of which was published in 1750; *Designs in Carpentry*, by the same author, printed in 1759; several pieces of carpentry in *A Complete Body of Architecture*, written by Isaac Ware, and published in 1768; *The Carpenter's and Joiner's Repository*, by William Pain, printed in 1778; *The Carpenter's Pocket Directory*, by the same author, printed in 1780; *The Golden Rule*, by the same author, printed in 1781; *The British Palladio*, by the same author, printed in 1788; *The Practical Builder*, and *The Practical House Carpenter*, by the same author, printed in 1791; *The Carpenter's New Guide*, by Peter Nicholson, the last editiou of which appeared in 1808; *The Carpenter's and Joiner's Assistant*, by the same author, a third edition of which was printed in 1810; various articles on carpentry, in Rees's *Cyclopædia*; *A Treatise on Carpentry*, in the *Edinburgh Encyclopædia*; and a treatise on the same subject, in the *Mechanical Exercises*, published in 1812, all by the same author; A long article on Carpentry, in a Supplement to the *Encyclopædia Britannica*, written by Professor Robison, of Edinburgh; and an article on carpentry, in *A Course of Lectures on Natural Philosophy and the Mechanical Arts*, by Thomas Young, M. D. Professor of Natural Philosophy in the Royal Institution of Great Britain; and some valuable articles on carpentry in the *Architectural Dictionary*, now publishing by Mr. Peter Nicolson, six parts of this Dictionary are already published; and if we may be allowed to consider these as a criterion of the work, we feel ourselves perfectly justified in pronouncing it to be one of the most useful of the kind that was ever published. It may not be uninteresting to the reader to take a view of these different works.

The articles on carpentry by Godfrey Richards, comprise "Rules and instructions for framing all manner of roofs, whether square or bevel, either above or under pitch, according to the best manner practised in England."

"Also to find the length of hips and sleepers, with the back or hip mould, never yet published by any architect, modern and antique; a curiosity worth the regard, even of the most curious workmen; exactly demonstrated by that ingenious architect, Mr. William Pope."

"Instructions to find the length and back of the hip, so as it may answer the side and the end of the perpendicular line of the gable end, the two skirts, the side of the roof in plano, or lying in legment with the hip and gable end, the diagonal and perpendicular lines being laid down proportional to any breadth or length, by which the most ingenious may serve himself, and an ordinary capacity (already acquainted with the use of the ruler and compass) may plainly demonstrate all the parts of a roof, whether square or bevel, above pitch or under pitch, by lines of proportion."

"To find the length of the hip."

"To find the back of the hip, so that it may answer both sides and ends of the roof, whether square or bevel."

"Of roofs bevel at one end, and square at the other, the gable end square, and the bevel end hipped."

"To find the length of each hip, distinct, one from

from the other, of the longest hips. To find the back of the longest hip. To find the shortest hip. To find the back of the hip."

"Of a roof bevel at both ends, and broader at one end than the other."

The subjects treated of in *Moxon's Mechanical Exercises*, are, "AC, BD, CD, NO, *Ground-plates, Wall-plates, Bressummers, Lintels, the Thickness of the Wall.*

A B, *Also a Ground-plate, or Ground-sell.*

P P, *The Summer.*

Q Q Q, *Girders.*

I, *The Well-hole for the Stairs, and Stair-case.*

M, *Leaving a way for the Chimnies.*

b b, Trimmers for the Chimney-way and Stair-case.

a a a a, Joists.

Of Framing for the Floors.—Figure 1 Plate 9.—The four Plates, A B, A N, N O, and B O, lying on the foundation, are called Ground-plates. They ought to be formed of good oak, and for this size of building, about eight inches broad, and six inches deep. They should be framed into one another with a tenon and mortise. The longer ground-plates, A N, and B O, are commonly tenoned into the front and rear ground-plates, A B, and N O, and into these two-side ground-plates, mortises are made for the tenons at the ends of the joists, which should be fitted somewhat loosely in, at about ten inches distance from one another, as in the draft. These ground-plates must be bored with an inch and half Auger, and well pinned into one another with round oaken pins, made tapering towards the point, and so strong, that with the hard blows of a mallet, they may drive stiff into the auger-hole and keep the tenon firmly in the mortise. The manner of making a tenon and mortise is taught in Joinery but because the stuff Carpenters work upon, is generally heavy timber, and consequently not so easily managed as the light stuff joiners work upon; therefore they do not at first pin their tenons into their mortises with wooden pins, lest they should be out of square, or any other intended position; but in laying a block or some other piece of timber under the corner of the frame-work in order to bear it hollow off the foundation, or whatever else it lies upon, hook-pins are driven into the four auger-holes in the corners of the ground-plates, and one by one fit the plates either to a square, or any other intended position. And when so fitted, the hook pins are driven out, and the wooden pins are driven in, (as aforesaid) and when the wooden blocks have been taken away one by one, from under the corners of the frame, it is permitted to fall into its place.

"But before they pin up the frame of ground-plates, they must set in the summer marked P P, and the girders Q Q, and all the joists marked *a a a a*, &c. and the trimmers for the stair-case, and chimney-way marked *b b*, and the binding joists marked *c c*, for else you cannot get their tenons into their respective mortise-holes. They fit all these in, while the frame of ground-plates lies loose, and may, corner by corner, be opened to let the respective tenons into their respective mortises, after which they frame the raising-plates just as the ground-plates are framed, and then frame the roof into the raising-plates with beams, joists, &c.

"The summer is in this ground-plate placed at 25 feet distance from the front, and is to be of the same scantling as the principal plates, for reasons which shall be shewn hereafter. And the girders are also to be of the same scantling as the summers and ground-plates. Though, according to the nice rules of architecture, the back-girder need not be so strong as the front-girder, because it bears but at 14 feet length; and the front-girder bears at 24 feet length; yet carpenters (for uniformity) generally make them so, unless they build an house by the great, and are agreed for the sum of money, &c.

"The joists bearing at 8 feet, (as here they do) are to be 7 inches deep, and 3 inches broad.

"The trimmers and trimming joists are 5 inches broad and 7 inches deep, and these joists, trimmers, and trimming joists, are all to be pinned into their respective mortices; and then their flatness is tried with the level, as was taught.

OF SETTING UP THE CARCASS.

"Though the ground-plates, girders, &c, be part of the carcass, yet I thought fit in the last section they should be laid, before I treated of the superstructure, which I shall now handle. The four corner posts called the principal posts marked A A, should be each of one piece, so long as to reach up to the beam of the roof, or raising-plate, and of the scantling as the ground-plates, viz. 8 inches broad, and 6 inches thick, and set with one of its narrowest sides towards the front. Its lower end is to be tenoned, and let into a mortise made near the corner of the ground-plate frame; and its upper end hath also a tenon on it, to fit into a mortise made in the beam of the roof, or rasing-piece.

"At the height of the first story in this principal post, must be made two mortises, one to receive the tenon at the end of the bressummer that lies in the front, and the other to entertain the tenon at the end of the bressummer that lies in the return side.

"Two such mortises must also be made in this principal post, at the height of the second story, to receive the tenon at the ends of the bressummers for that story.

"Though I have spoken singularly of one principal post, yet as you work this, you must work all four principal posts; and then set them plumb upright, which you must try with a plumb-line.

"Having erected the principal posts upright, you must enter the tenons of the bressummers into their proper mortises, and with a nail or two, (about a single ten or a double ten) tack one end of a deal board, or some other like piece of stuff to the bressummer, and the other end to the framed work of the floor

floor, to keep the principal posts upright and in their places. Then set up the several posts between the principal posts; but these posts must be tenoned at each end, because they are to be no longer than to reach from story to story, or from intertie to intertie, and are to be framed into the upper and under bressummer. If the interties be not long enough, they set up a principal post between two or three lengths, to reach from the ground-plate up to the raising-plates.

"It is to be remembered, that the bressummers and girders are laid flat upon one of their broadest sides, with their two narrowest sides perpendicular to the ground-plot; but the joists are to be laid contrary; for they are framed so as to lie with one of their narrowest sides upwards, with their two broadest sides perpendicular to the ground-plot. The reason is, because the stuff of the bressummers and girders are less weakened by cutting the mortises in them in this position, than in the other position; for as the tenons for those mortises are cut between the top and bottom sides, and the flat of the tenons are no broader than the flat of the narrowest side of the joists; so the mortises they are to fit into, need be no broader than the breadth of the tenon, and the tenons are not to be above an inch thick, and consequently the mortises are to be made with an inch mortice chissel, as is shewn in joinery, for great care must be taken that the bressummers and girders be not weakened more than needs, lest the whole floor dance.

"These tenons are cut through the two narrowest sides, rather than between the two broadest sides, because the stuff of the girders retains more strength when least of the grain of the stuff is cut; and the tenons being made between the narrowest sides of the joists, require their mortise holes no longer than the breadth of that tenon; and that tenon being but an inch thick, requires its mortise to be but an inch wide to receive it; so that you mortise into the girder no more than three inches wide with the grain of the stuff, and one inch broad contrary to the grain of the stuff. But should the tenon be cut between the two broad sides of the joists, the mortise would be three inches long, and but one inch broad, and consequently you must cut into the girder three inches cross the grain of the stuff, which would weaken it more than cutting six inches with the grain, and one inch cross.

"But it may be objected that the tenons of the joists being so small, and bearing at an inch thickness must needs be too weak.

"Answer, first, though the tenons be indeed but an inch thick, and three inches broad; yet the whole bearing of the joists do not solely depend upon their tenons; because the girders they are framed into, prove commonly somewhat wainy upon their upper sides, and the joists are always scribed to project over that waynniness, and so strengthen their bearing, by so much as they project over the roundness or waynniness of the upper side of the girder.

"Secondly, the floor is boarded with the length of the boards athwart the joists, and these boards firmly nailed down to the joists, which also adds a great strength to them.

"Thirdly, the joists are seldom made to bear at above ten foot in length, and should by the rule of good workmanship, not lie above ten inches asunder at the most; so that this short bearing and close discharging of one another, renders the whole floor firm enough for all common occupation. But if the joists do bear at above ten foot in length, it ought to be the care of the master workman to provide stronger stuff for them, viz. thicker and broader. If not, they cut a tusk on the upper side of the tenon, and let that tusk into the upper side of the girders.

"Having erected the principal post, and other posts, and fitted in the bressummers, girders, joists, &c. upon the first floor, they pin up all the frame of carcass-work. But though the girders and joists described for this first floor, lie proper enough for it; yet for the second story, and in this particular case, the joists lie not proper for the second story; because in the second story we have described a balcony.

"Therefore in this case you must frame the front-bressummer about seven inches lower into the principal posts; because the joists for the second floor are not to be mortised into the bressummer to lie even at the top with it, but must lie upon the bressummer, and project over it so far as the balcony is designed to project beyond the upright of the front. And thus laying the joists upon the bressummer renders them much stronger to bear the balcony, than if the joists were tenoned into the front of the bressummer, and projected from it into the street.

"But the truth is, though I have given you a draft of the joists lying athwart the front and rear for the first floor, you may as well make them range with the two sides on the first floor. But then the bressummer that reaches from front to rear in the middle of the floor must be stronger; and girders must then be tenoned into the bressummer and the ground-plates, at such a distance, that the joists may not bear at above ten foot in length. And the tenons of the joists must be tenoned into the girders, so that they will then range with the two sides.

"But a word more of the bressummer; I say (as before) that the bressummer to bear at so great length must be made stronger, though it should be discharged at the length of the shop, (viz. at 25 feet) with a brick wall, or a foundation brought up of brick. But if it should have no discharge of brick-work, but bear at the whole 40 feet in length, your bressummer must be yet considerably stronger than it need be were it to bear but 25 feet in length; because the shorter all the bearings of timbers are, the firmer they bear. But then the framing work will take up more labour, and in many cases it is cheaper

er to put in stronger stuff for long bearings, than to put a girder between to discharge the length of the joists to be framed into the girders.

" But to make short of this argument, I shall give you the scheme of scantlings of timber, at several bearings, for summers, girders, joists, rafters, &c. as they are set down in the Act of Parliament for rebuilding the city of London, after the late dreadful fire; which scantlings were well considered by able workmen, before this adoption was reduced into an Act.

Scantlings of Timber for the first sorts of Houses.

		Ft.	In.	In.
For the Floor	Summers under	15	12	and 8
	Wall-plates	—	7	and 5
For the Roof	Principal Rafters under	15 Ft.	at foot..8, at top..5	6 Inch
	Single Rafters		4 and 3 inches.	

	Length Foot.	Thickness.	Depth.	
Joists to	10	3	and 7	Inches.
Garret Floors	8	-	and 6	

Scantlings of Timber for the other two sorts of Houses.

		Ft.	Ft.	Breadth. In.	Depth. In.		Thickness. In.	Depth. In.
For the Floor.	Summers or Girders which bear in length from	10..to	15	11	and 8	Joists which bear 10 feet	3	6
		15..to	18	13	and 9		3	7
		18..to	21	14	and 10		3	7
		21..to	24	16	and 12		3	8
		24..to	26	17	and 11		3	8

		In.	In.
For the Floor.	Principal Discharges upon Piers in the first Story in the Fronts	13..and	12
		15..and	13
	Binding Joists with their Trimming Joists	Thickness. Inches. 5—depth equal to their own floors.	
	Wall-Plates, or Raising Pieces and Beams	10..and	6
		8..and	6
		7..and	5
	Lintels of Oak in the 1st and 2d story	8..and	6
	Lintels of Oak in the 3d story	5..and	4

		Length. Ft.	Ft.	Thickness. In.	In.
For the Roof.	Principal Rafters from	15..to	18	at foot..9, at top..7	7
		18..to	21	at foot..10, at top..8	8
		21..to	21	at foot..12, at top..9	8½
		24..to	26	at foot .13, at top..9	9

		Length. Ft.	Ft.	In.	In.
For the Roof.	Purlins from	15..to	18	9	8
		18..to	21	12	9

		Ft.	In.	In.
For the Roof.	Single Rafters not exceeding in length	9	5	4
	Single Rafters not exceeding in length	6	4	3½

Scantlings for Sawed Timber and Laths, usually brought out of the West Country, not less than

	Ft.	Breadth. In.	Thickness. In.
Single Quarters in length	8	3½	1½
Double Quarters in length	8	4	3½
Sawed Joists in length	8	6	4
Laths in length	5 / 4	1½	1 quarter and ½ inch.

			Inches.
Stone	First sort of Houses	Corner Piers	18 square
		Middle or Single Piers	14 and 12
		Double Piers between House and House	14 and 18
		Door-Jambs and Heads	12 and 8

			Ft. In.
Where stone is used to keep to these Scantlings	2d and 3d sorts	Corner Piers	2 6 square
		Middle or Single Piers	- 18 square
		Double Piers between House and House	24 and 18
		Door Jambs and Heads	14 and 10

	Ft.	Thickness.	
Scantlings for Sewers	3 wide	Side-walls. 1 brick ½	Bottom paved plain, and then 1 brick on edge circular.
	5 high	Arch..1 brick on end	

We next proceed to Smith's *Carpenter's Companion*, in which are many observations, very judicious and worthy to transcription; the introduction of this work, is interesting, and commences in the following manner.

" The usefulness of carpenter's work in building, and the little notice taken of it by authors who have treated of architecture, and the few there be that rightly understand it, prompted me to write the following treatise.

" Carpenter's work is one of the most valuable branches of architecture; it was contemporary with the first ages of the world; and with the knowledge of this art, Noah closely and firmly connected those timbers in the ark, which were so nicely wrought, that they not only kept the water from penetrating into it, but were proof against the tempest and the rolling billows, when, in its womb, it carried all the tenants of the earth and air.

" Those naval preparations, through all ages of the world, as well as those stupendous temples and edifices, erected in all countries, demonstrate the perfection of this art. The innumerable *floating buildings*, which roll from one country to another, through tempestuous storms, tossed from the mountain's height to the depths of the ocean, without injuring the vessel, evidently shew the vast use and judgment of carpenter's work.

" But as that branch of it which relates to *templar* or *domal* uses, is the subject of this work, I shall only treat of its usefulness in them; and may venture to affirm that carpenter's work is the chief tie and connection of a building; it is the ligament which binds the walls together.

" The bond-timbers, which strengthen and tie the angles of a building, and prevent its separating, is the work of the carpenter. Linteling over doors and windows, with other dischargements of weight, it is his care to perform.

" Bond timbers in cross walls, when settlements happen, if they are well applied, prevent the cracking of the walls, for they keep the whole together, and every part settleth alike, which would fill the buildings with gaps and chasms if neglected.

" Next, the floors; the rightly framing them, by trussing the girders, by placing them on joists, so that they come near no funnels of chimnies; the manner of tenanting, tusking, framing of timbers for chimneys, stairs, &c. I say, all these are the business of the carpenter to see carefully performed.

" Partitions of timber, their manner of trussing to prevent cracking, settlements, &c. and the discharge of weight of girders, beams, or cross walls, is carpenter's work; as is, likewise, the framing of timber bridges.

" Roofs of various sorts, for common houses, large edifices;

edifices, or churches, their manner of framing, the height of their pitch, their strength, usefulness, &c. with the various manner of performing all these works, is the subject of this treatise, which I have rendered intelligible to every capacity, by designs of several sorts, and have described them in such a manner, that will render the work useful to carpenters; in particular, such who are acquainted with the manner of performing these operations of framing.

"If it should be objected, that there are few things here treated of, but what every carpentor knows, I could wish such objectors had been at the pains I have taken to inform the world, since I reap no advantage by it, but the satisfaction of communicating any thing which may prove serviceable to my countrymen.

"The first thing which the carpenter must consider for the carrying on a building, is the plan, in which you are to prepare your timber in having it cut into proper scantlings, which shall be hereafter noted.

"You are to prepare for lintelings and bond-timbers; for lintels over doors or windows, stuff of five inches thick and seven broad, and it is a slight way of building to put in any of less scantling; as for door-cases, their manner of making, and scantlings of stuff, it is needless to speak of; it is the best way to have them put in when the foundations are brought up high enough for them. Bond-timbers should be dovetailed at the angles of the building and cross walls. And here note, that it is a durable, though expensive way, to have all fir timber, which is laid in the walls of the building, to be pitched with pitch and grease mixed together; the quantity of grease, one pound to four pounds of pitch. All these things are the care of the carpenter.

"Bond-timbers should be four or five inches thick for cross walls, and in the angles of a building, six or seven inches, and proportionably broad; six or eight feet long in each wall; and it would not be amiss to place them six or eight feet distant all the height of the building, in every angle and cross wall; these, if a building be on on infirm foundation, cause the whole to settle together, and prevent the cracks and fractures which happen if this be neglected.

"We come now to the floors, in which these things are to be observed; the magnitude of the room, the manner of framing, and the scantlings of the timber. For the first, you are to observe to lay the girders always the shortest way, and not to have a joist at any time exceeding twelve feet in length.

"The first common method of framing floors, is where the joists are framed flush with the top of the girder." *(The trimming-joists supposed to come against chimneys and stairs, are always thicker than common joists.)* "Being weakened by mortising. Scantling of joists, when a floor is framed in this manner, ought to be as followeth:

Common Joists.		Trimmers.	
ft. long	Scantling in inches.	ft. long.	Scantling in inches.
5	7 × $2\frac{1}{4}$	5	7 × 3
6	7 × $2\frac{1}{2}$	6	7 × 4
8	7 × $2\frac{1}{4}$	7	7 × 5
9	8 × 3	8	8 × 4
10	8 × $3\frac{1}{4}$	9	8 × 5
11	8 × $3\frac{1}{2}$	10	9 × 6
12	9 × 4		

"These are such proportions, as will render the work sufficiently capable of sustaining any common weight.

"The next manner of framing floors, is with binding joists framed flush with the under side of the girder; and about three or four inches below the top of the girder, to receive the bridgings, which are those which lie across the binding-joists, and are pinned down to them with pins of wood, or spikes of iron. These binding-joists should be framed about three feet, or three feet six inches distant from one another, and their thickness four or five inches, or in the proportion to the length of their bearing, as trimming joists.

"These floors, if they settle out of a level with the building, are made level when the bridgings are put in, which is generally after the building is covered in, and nearly compleated; they are generally double tenanted. The binding-joists are chased, and the ceiling-joists tenanted into them, and put in generally after the building is up. These ceiling joists should be 13 or 14 inches apart, and the scantling 2 or 3 inches square, and in large buildings 3 and 4. As for the bridgings, which lie on the top of the binding-joists, they may be placed 12 or 14 inches distant, their scantling 3 and 4, or $3\frac{1}{2}$ and 5; their bearing being only from binding-joist to joist, which is three feet, or three feet 6 inches, and these are laid even with the top of the girder to receive the boarding. We come now to speak of girders; and first, for their scantling, take these proportions:

ft. long	Scantling in inches.		
	B.		D.
10	8	×	10
12	$8\frac{1}{2}$	×	10
14	9	×	$10\frac{1}{2}$
16	$9\frac{1}{2}$	×	$10\frac{1}{2}$
18	10	×	11
20	11	×	12
22	$11\frac{1}{2}$	×	13
24	12	×	14

"The

And observe, that as every weight, added, to the weight of the timber in the floor, in itself occasions it to settle, the girders should be cut camber; if a 10 feet bearing, half an inch camber; if 20 feet bearing, an inch camber, &c. in proportion to the length of the bearing.

"And farther to strengthen the girder, and prevent its sagging, as it is called among workmen, that is, its bending downwards, I have given you several ways of trussing girders, which have been most of them practised.

"The manner of trussing these girders, is, first, to saw the girder down the middle, the deepest way; then take two pieces of dry oak, about 4½ or 5 inches wide, and 4 inches thick; let half the piece be let in one side of the girder, and half into the other.

"Another way, which is by cutting the girder through, and driving a wedge against the ends of the trusses. When these are thus prepared, bolt them together with iron bolts and keys; or much rather, a screw at the end of the bolt.

"Some carpenters cut their girders down the middle, and bolt them together, without trussing, only changing the ends different from what they grew, whereby the grain of the wood is crossed, and it becomes much stronger than if it had continued without sawing down the middle, and thus putting it together.

"Some in trussing girders, make use of other trusses.

"The girder being thus trussed and put together, proceed in framing the joists, as in common floors. The strongest way being double tenanting and tusking, as is shewn in the binding-joists. Before I leave this part of floors, I shall observe to you that the best and most workmanlike manner of framing floors, is to plane the upper edge of your joists straight; for the straighter and truer your joists lie, the truer your boarding will lie, which is a great ornament to a magnificent room; but if you frame without binding-joists, and lay on bridgings, plane the bridgings, and lay them very straight and level; this care taken, will save a great deal of trouble in laying down the boarding, which you are often forced to chip and fur up, to make them lie even, and those furrings are not only troublesome, but are apt to give way, and occasion the creeking of the boards as you walk on them. It would be a good way to turn arches of brick over the ends of the girders of the floors, because if any alteration happens, they are easily taken out.

"I come now to partitions of timber, with their manner of framing. Timber partitions have these properties attending them; they take up less room, and are cheaper than those of brick.

"As to roofs, there is a plate to go round a building, which may or may not be deemed a part of the roof; it may be deemed the foundation and tie of the roof and walls, or it may be taken as only that on which the roof lieth. These plates are to be dovetailed at the angles and tenanted together in their length, several ways. The beams of the roof, which serve as girders to the ceiling-floors, (and into which all the principal rafters of the roof are tenanted) are dovetailed, or what by workmen is termed cogged down to the plate, which prevents its flying out from the foot of the rafter, whose butment is against it; and in the angles of a building, pieces dovetailed across the angles of the plate, serve to keep it from spreading, and is the foot of the hip.

"The common pitch of roofs is to have the rafter's length, if it span the building at once, to be three-fourths of the breadth of the building. Some make them flatter, as a pediment pitch; and the old Gothic way was to make them the whole breadth.

"The common pitch is not only unpleasing to the eye, but is attended with this inconvenience; if there is a gutter round the building, the steepness of the roof occasions the rain to come with so sudden a velocity into the pipes, which are to convey the water from the gutters, that they fill the gutter; and sometimes so fast, that the water runneth over the covering of the roof, and does great injury to the timber, &c. of the building; and the steeper the roof is, the longer the rafters, and the greater quantity of timber must be used in the roof, as well as the more weight from the great quantity of timber, and the weakening the principal timbers, by adding more to its own weight.

"And the pediment-pitch is inconvenient, in lying too flat, for those climates so frequently subject to rain, and heavy snows, which last would press and vastly incommode the building, and would lie much longer on the roof, its declivity being so small; besides, in keen winds, attended with rain, the rain would drive in under the covering of slate or tiles, and create much decay in the timber.

"Proportion of beams whose bearing varieth, take the following rule:

Length of beam in feet.	Scantling in inches.		
12	6	×	8
16	6¼	×	8½
20	6½	×	9
24	7	×	9½
28	7½	×	9½
32	8	×	10
36	8½	×	10½
40	8½	×	11
44	9	×	12

"The principal rafter should be nearly as thick at the bottom as the beam, and diminish in its length

length one-fifth or one-sixth of its breadth: the king-posts should be as thick as the top of the principal rafter, and the breadth according to the bigness of the struts you intend to let into them, the middle part being left something broader than the thickness.

"Struts may diminish as the rafters do, one-fifth, or one sixth of their length. In placing struts and collar-beams, the dividing the rafter into as many equal parts as you propose bearings, is the rule, because every part of the principal will have its equal distant bearings.

"Purlins are of the same thickness as the principal rafter, and the proportion of the breadth is six to eight; that is, if the rafter be six inches thick, let the purlins be six inches thick, and eight inches broad; if it be nine inches thick, the breadth of the purlins is twelve inches broad, &c.

"N. B. The purlins are those pieces into which the small rafters are tenanted, and they are tenanted into the principal rafter. Length of purlins is generally from six to eleven feet, not exceeding that length.

"Small rafters; their scantlings two inches and a half, and four inches; three inches, and four inches and a half; and three inches and a half, and five inches; according to the magnitude of the roof and length of the rafters. Small rafters should not exceed seven feet in length in a purlined roof; if it happen that the length of the principal be above fifteen feet, it is best to put in two tier of purlins in the length of the rafter."

In respect to the construction of roofs for coves, he has the following observations: "The use of coving a room of considerable height, is, first, the making of it much lighter than it would otherwise be, if level in the ceiling; the rays of light in a cove are reflected back again into the rooms, which would be otherwise lost and confused in a room with a flat ceiling.

"Likewise, all rooms with circular roofs or ceilings are more commodious and useful for entertainment, for music, &c. The angles of incidence are always equal to those of reflection; so the undulation of sounds flying on any cove, or spherical part of a building, reverberate on the audience; and if spherical, no part of the sphere can receive the vibration, but it will return in the same direction from whence the undulation first began. The reflecting rays of light, and the reverberation of sounds, proceed from the same cause, and from incidents naturally affecting the eye and the ear."

Mr. Smith's work is illustrated by thirty-three plates, twenty of which are designs of roofs, and five are plans or elevations of wooden bridges.

The next work to be reviewed, is the *British Carpenter*, by Mr. Francis Price, whose treatise has obtained the recommendation, of Messrs. Hawksmoor, James, and Gibbs. From this we shall also quote the introductory part, with some descriptions and observations, which, though they may not be so methodically arranged, as those of the last author, are, in general correct, and well founded.

"As all buildings are composed of three principal parts, viz. strength, use, and beauty, therefore carpentry naturally comes in among the essential heads of architecture. It is an art that has been taken notice of, by all the most famous architects; therefore these and the like circumstances, prompted me to compile the most approved methods of connecting timber together, for most of the various uses in buildings, with the rules necessary to be observed therein; but when I considered such a treatise might not give a sufficient variety, therefore it appeared necessary to add several other things appertaining to the art, in order to make the whole particularly useful.

"I have used my utmost endeavours to render this treatise not only intelligible to carpenters, but at the same time to be of use to the ingenious theorist in building; and have digested it in such a manner as to need little or no explanation, otherways than carefully inspecting the *Plates*.

"Nevertheless it may not be improper, in this place, to mention some general observations. There is a moisture in all timber; therefore all bearing-timber ought to have a moderate camber, or roundness, for till that moisture is in some sort dryed out, the said timber will sag with its own weight: and that chiefly is the reason girders are trussed and used, as in its place will be shewn. But here observe that girders are best trussed when they are first sawn out, for by their drying and shrinking, it tightens the trusses in them yet more.

"Observe also, that all beams, or ties, be cut, or forced in framing, to a camber, or roundness, such as an inch in the length of eighteen feet; and that principal rafters be also cut, or forced up to a camber, or roundness, as before. The reason of this is, all trusses, though ever so well framed, by the shrinking of the timber, and weight of the covering, will sag, and sometimes so much as to offend the eye of the beholder; so that by this preparation, your truss will ever appear well.

"Also observe, that all case-bays, either in floors or roofs, do not exceed twelve feet if possible: that is, do not let your joists in floors, your purlins in roofs, &c. exceed twelve feet in their length or bearing; but rather let the bearing be eight, nine, or ten feet; which should be observed in forming a plan.

"Also in bridging floor, do not place your binding, or strong joists above three, four, or five feet apart; and that your bridgings, or common joists, are not above ten or twelve inches apart, that is, between one joist and the other.

"Here also observe, never to make double tenants or tenons, for bearing uses, such as binding joists,

joists, common-joists, or purlins; for, in the first place, it weakens very much whatever you frame it into; and, in the second place, it is a rarity to have a draught in both tenons, that is, to draw your joint close by the pin; for the said pin, by passing through both tenons, (if there is a draught to each,) must bend so much, that without the pin be as tough as wire, it must needs break in driving, and consequently do more hurt than good."

He then proceeds to notice the scarfing of beams, the method of trussing girders, and the modes of connecting the various joints of roofing. He next describes bridging floors, and the plan of laying down the sides of roofs in plano, in adverting to which, he shews the backings of the hips, according to Pope's principle, and how the side joint of a purlin may be found, so as to cut it by a templet, supposing there be no room, or occasion to frame it into the hip.

Mr. Price's rules for finding the pitch of the rafters for different coverings, deserve attention.

"Take any width, to be covered with lead; divide the width, first into two parts; and one of them, again into four, as 1, 2, 3, 4; at 2, and with two of these parts, describe the quarter circle, which gives a proper pitch, or slope to be covered with lead, and is called a pediment pitch.

"Again, take any width, and to be covered with pantiles; divide it, as before, into two parts, and again one of them into four, as 1, 2, 3, 4: with three parts, as at 3, describe the quarter circle, which gives a proper pitch for the use."

"Also take any width, and to be covered with plain tiles, divide it into two parts, with one make a quarter-circle, as the pricked line shews; which gives a pitch, or slope, proper for use,

Mr. Price next presents his readers with some designs for the fronts of buildings, required to have the ground story open, and to be supported with story posts; his observations next apply to wooden bridges, and he gives the following rules for the construction of one :—

"I have inserted a bridge that may be more acceptable than the foregoing ones, because it is adapted to public and private uses, by being so formed of small parts, that it may be carried to any assigned place, and there put together at a short notice.

"This bridge H, *Figure* 2, *Plate* 9, I suppose to consist of two principal ribs, as i, k, made thus, the width of the place is spanned at once by an arch rising one sixth part of its extent; its curve is divided into five parts, which I propose to be of good seasoned English oak plank, of three inches thick, and twelve broad, their joint or meeting tends to the centre of the arch; within this rib is another, cut out of plank as before, of three inches thick, and nine broad; in such sort as to break the joints of the other. In each of these ribs, are made four mortises, of four inches broad, and three high, and in the middle of the said nine inch plank, (these mortises are best set out with a templet, on which the said mortises have been truly divided and adjusted;) lastly, put each principal rib up in its place, driving loose keys into some of the mortises, to hold the said two thicknesses together; while other help is ready to drive in the joists, which have a shoulder inward, and a mortise in them outward; through which, keys being drove, keeps the whole together: on these joists, lay your planks, gravel, &c. so is your bridge compleat, and suitable to a river, &c. of thirty-six feet wide.

"In case the river, &c. be forty or fifty feet wide, the stuff should be larger, and more particularly framed; as is shewn in part of the plan enlarged, as I; these planks ought to be four inches thick, and sixteen wide; and the inner ones that break the joints, four inches thick, and twelve broad; in each of these are six mortises, four of which are four inches wide, and two high; through these are drove keys, which keep the ribs the better together; the other two mortises are six inches wide, and four high; into these are framed the joists, of six inches, by twelve; the tenons of these joists are mortised to receive the posts, which serve as keys; as is shewn in the section K, and the small keys are shewn as in L; all which inspection will explain. That of M, is a method whereby to make a good butment in case the ground be not solid; and is by driving two piles perpendicularly, and two sloping; the heads of both being cut off so as to be embraced by the cill, or resting-plate; which will appear by the pricked lines drawn from the plan I, and the letters of reference.

"All that I conceive necessary to be said farther, is, that the whole being performed without iron, it is therefore capable of being painted on every part, by which means the timber may be preserved; for though in some respects iron is indispensably necessary, yet, if in such cases where things are, or may be often moved, the iron will rust and scale, so as that the parts will become loose in process of time; which, as I said before, if made of sound timber will always keep tight and firm together. It may not be amiss to observe, that whereas some may imagine this arch of timber is liable to give way, when a weight comes on any particular part, and rise where there is no weight, such objectors may be satisfied that no part can yield, or give way, till the said six keys are broke short off at once, which no weight can possibly do.

Mr. Price, speaking of the circular domes, observes, that "of what has been hitherto described, nothing appears so beautiful when done, as domes, or circular roofs; and as far as I can perceive, nothing has appeared so difficult in doing, therefore it will be proper to speak something of them."

Figure 3, *Plate* 9.—"Let B represent a plan, in which

which let b, b, b, be the plate on the supposed wall; and let c, c, c, be the kirb on which stands a lantern, or cupola; also let a, a, a, represent the principal ribs.

"From the plan B, make the section A; in which the kirb, or plate b should be in two thicknesses; as also that of c, by which it is made stronger; and indeed the principal ribs would be much better to be in two thicknesses. The best timber for this use is English oak; because abundance of that naturally grows crooked. As to the curve or sweep of this dome A, it is a semicircle; although in that point, every one may use his pleasure; and in it are described the purlins d, e, from which perpendiculars are dropped to the plan B; so that f is the mould the lower purlins are to be cut out by, before they are shaped or squared for use; and that of g, is the mould for the upper purlins. I rather shew it with purlins, because under this head, may be shewn the manner of framing circular roofs in form of a cone.

"To shape these purlins, observe, in A, as at d and e, the are so squared, that the joints of the supposed small ribs are equal. Observe, as at e, the corners of the purlin, from which the perpendiculars are let fall to the plan B. So that your purlin being first cut out to the thickness required, as appears in e, and also to the sweep f; so that k is the mould for the bottom, and l the mould for the top; by which, and the lines for the cornets of the said purlin e, the same may be truly shaped and squared.

"N. B. This particular ought to be well digested, it being a principal observation in a circular roof.

"And from the purlin d, in the section A, perpendiculars are dropped to the plan B; and in which it appears that h is the mould for the top, and i the mould for the bottom; so may this be squared, which compleats the performance. As to other particulars, due inspection will explain them. If any should say, a dome cannot be done so safe without a cavity as usual, let them view St. Stephen's, Walbrook, Stock's-market, built by that great architect, Sir Christopher Wren."

"On perusing the foregoing dome, which has no vacancy, and that of St. Paul's dome, that has so great a one, I thought necessary to represent one at a medium, and which seems very concisely adapted to a temple, of eighty feet diameter in the clear; the walls I have represented one eighth part of the opening.—*Figure* 4.

"I suppose this a temple standing clear from other buildings, so that one may have a beautiful view of it; as to its performance, it is sufficiently explained in the foregoing plate; the vacancy gives a great strength to it, and renders it more capable of bearing the cupola; for, by framing that part of the section C, as at a, a, in the manner represented in D, it not only gives an opening for the light to illuminate the inside, but gives a great strength to the whole.

"N. B. In all roofs of a great extent, the wind is to be prepared against, as strictly as the weight of the materials which cover it, because it has so great a force in storms of wind, and rain; that is, it acts with more violence than the materials do, they being, (what we may call) a steady pressure.

"The plan D, may be observed to consist of two square frames of timber, crossing each other, and halved together, the corners of which, and the intersections prove a very good tie, and at the same time is of a resisting nature; so that it becomes the chief connection in the dome.

"I suppose this dome to consist of sixteen principal ribs; which is a mean betwixt the foregoing one, which has but eight, and that of St. Paul's, that has thirty-two; this also may be framed with purlins, or may have ribs let into these principal ones, horizontally; so that the boards that cover it, may stand upright as it were; although I don't think that a material point. If the plan were to be prepared for twelve principal ribs, then two equilateral triangles, crossing each other, might better suit than to half two squares together."

He next shews the method of covering polygonal buildings.

In *Figure* 5, "let A be the plan, the upper part of which is half an octagon. It is observable, that a circular roof, as B, should extend no farther than the upright of its support, and there made so as to carry off the water; whereas an ogee roof, as C, may extend to the extremity of the cornice, without injury to its strength, or offence to the eye of the most curious: also, a hollow roof, as D, may extend to the extremity of the cornice.

"It appears to me, that many angles of a cupola give it beauty; therefore the sweep E, is a regular curve, the base line $l\,k$, being taken from the angle of the octagon in the plan A, as at $l\,k$. This curve E, is divided into a number of equal parts, in order to trace the common rib, F, from the said angular rib E; observe, in A, the base of the common rib, $f\,l$, which is placed in F, as from l to f; continue the perpendicular, l, at pleasure; take the base $l\,k$, in E, on which are the perpendiculars dropped from the curve, and observe to place that distance, $k\,l$, in E, from f, in F, to any part where it cuts the perpendicular l in F, as at m; from these divisions raise perpendiculars, so by continuing the base lines from the divisions in E, to these perpendiculars in F, their intersection, or meeting, is a curve or sweep exactly agreeable, and which, indeed, may serve as a standard rule to trace any moulding whatever.

"To back the said angle-bracket, D, observe to describe the thickness of it on your plan, as in A, at k, which shews how much your mould must be shifted, as may appear in D. This also may be

be observed to be a general rule for the backing of any bracket."

"In G, is the angular bracket of an O G roof, taken from the plan A; as at l, c, and H, is the common rib, or bracket *l*, *f*, traced from G, as above is shewn. As also the manner of backing the hip G, which must of course appear by inspection.

Figure 1 *Plate* 10, Let A be the plan of a vault to be centered for groins. At *a*, *b*, *c*, *d*, are piers, generally prepared in with the foundation, which bear the weight of the brickwork. First, resolve on the curve you would have, as *d e c*, being a semicircle, which is shewn by the section B. Begin in A at *d e c*; center through, as it were a common vault, and board it; which being done, to make your groin set centers, as from *a* to *c*, and from *b* to *d*, divide the curve *d e c* into four equal parts, as at *g* and *f*; so are *g*, *e*, *f*, small centers, you will want to nail on the centers first boarded, whose place, or plan is at *h*; these small centers may be put in at pleasure, according to the bearing of your boards, that is, as to the distance between each center. To make your groin straight on its base, at some little height over the centers, strain a line from *b* to *c*, or from *d* to *a*, from which drop perpendiculars on your boarding, first fixed at as many places as you please; there drive in nails, and bend a straight rod till it touch them all; and then, with a pencil or chalk, describe the curve so formed, to which bring the boards to be nailed on these little centers, and their joints will form a straight groin."

Figure 2. "Let C be a plan of greater extent, and which suppose to be supported by two piers, as *f*, *l*. The section D is composed of entire semicircles, then, consequently, your curves in the section E will be elliptical, as *b*, *n*, *d*, and may be described with a trammel. What was said in A explains this at one view.

"If these pillars should be in the way, view the plan and sections again: first, form the principal curve, as D at *a g h b*, being an ellipsis, so that the centers will be a Gothic sweep against the windows, as *e g a*: trace the curve *d h b* in E, agreeable to *e g a*, in D, with which center it, as shewn in A, and make good your groins to the sides: lastly, make a flat center, as at *g h i k*, which flatness is shewn in either of the profiles or sections D and E, and fix it on your centers before compleated, which, doubtless, due inspection will make plain, and hereby you avoid the pillars, which are equally firm.

"N. B. The cause of these centers against the windows being a Gothic arch, proceeds from their making part of the whole sweep or arch, which though it does not add to its beauty, it does to its strength in a particular manner.

"He next says, regarding variety, I have given here another method for vaults, and which, indeed, may give more pleasure to the reader, as being a curiosity never before published, and may appear more intelligible than that in the foregoing."

Figure 3—"View the plan G and its section H, which is composed of entire semicircles, as *b f e*: see also the section I, which is an ellipsis traced from *b f e* in H; but for use, nothing is more true than the trammel.

"See this plan again, and also its section I, from which is described the curvilinear face K, and also the face of the semicircular arches, as L, all being alike. And this is what I call a more accurate method for finding the groin, so as to be straight over its base, and at the same time gives a standard rule whereby to account for any curve, or face of a ceiling whatever. The curve in I is divided regularly, though seemingly into unequal parts, which being drawn to the groin in the plan G, as appears by the figures 1, 2, 3, 4, 5, 6, 7, 8, 9, and which are transferred into L at 1, 2, 3, &c. Also the circle *b f e* in H, is divided into eighteen equal parts; the half consequently into nine, which appears from *b* to *e* in L. This method doubtless will be plain, and therefore needs no farther explanation.

"That of K belongs to the section I, extended as it were, and that of L belongs to one of the small arches of H, also stretched out, they being all alike."

"N. B. To find the groin by a more common method, do thus; erect a straight piece of a board, or the like, on the corner of the pier the groin springs from, and drive in a nail at the point of the groin's meeting, on which fasten one end of a chalked line, straining it tight, slide it down the side of the said straight piece, and it will form the groin so as to stand perpendicularly over its base."

Mr. Price then shews the nature of oblique or rampant arches, with the manner of tracing the base or seat of the angle ribs of an annular groin, his table for the scantlings of timber, with accompanying remarks are too valuable to be omitted.

A TABLE

(*For the Table see the following Page.*)

A TABLE FOR THE SCANTLINGS OF TIMBER.

A Proportion for Timbers for small Buildings.				*A Proportion for Timbers for large Buildings.*			
Bearing Posts of Fir		**Bearing Posts of Oak**		**Bearing Posts of Fir**		**Bearing Posts of Oak**	
Height	Scantling	Height	Scantling	Height	Scantling	Height	Scantling
if 8 feet	4 inch. square	if 10 feet	6 inch sq	if 8 feet	5 inch sq.	if 8 feet	8 inch sq.
10	5	12	8	12	8	12	12
12	6	14	10	16	10	16	16
Girders of Fir		**Girders of Oak**		**Girders of Fir**		**Girders of Oak**	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 16 feet	8 ins. by 11	if 16 feet	10 ins. by 13	if 16 feet	9½ ins. by 13	if 16 feet	12 ins. by 14
20	10 12½	20	12 14	20	12 14	20	15 15
24	12 14	24	14 15	24	13½ 15	24	18 16
Joists of Fir		**Joists of Oak**		**Joists of Fir**		**Joists of Oak**	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 6 feet	5 ins. by 2½	if 6 feet	5 ins. by 3	if 6 feet	5 ins. by 3	if 6 feet	6 ins. by 3
9	6½ 2½	9	7½ 3	9	7½ 3	9	9 3
12	8 2½	12	10 3	12	10 3	12	12 3
Bridgings of Fir		**Bridgings of Oak**		**Bridgings of Fir**		**Bridgings of Oak**	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 6 feet	4 ins. by 2½	if 6 feet	4 inch by 3	if 6 feet	4 inch by 3	if 6 feet	5 ins. by 3½
8	5 2¾	8	5½ 3	8	5½ 3	8	6½ 3½
10	6 3	10	7 3	10	7 3	10	8 3½
Small Rafters of Fir		**Small Rafters of Oak**		**Small Rafters of Fir**		**Small Rafters of Oak**	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 8 feet	3½ ins. by 2½	if 8 feet	4½ ins. by 3	if 8 feet	4½ ins. by 3	if 8 feet	5½ ins. by 3
10	4½ 2	10	5½ 3	10	5½ 3	10	7 3
12	5½ 2½	12	6½ 3	12	6½ 3	12	9 3
Beams of Fir, or ties		**Beams of Oak, or Ties**		**Beams of Fir, or Ties**		**Beams of Oak, or Ties**	
Length	Scantling	Length	Scantling	Length	Scantling	Length	Scantling
if 30 feet	6 ins. by 7	if 30 feet	7 ins. by 8	if 30 feet	7 ins. by 8	if 30 feet	8 ins. by 9
45	9 8½	45	10 11½	45	10 11½	45	11 12½
60	12 11	60	13 15	60	13 15	60	14 16

Principal Rafters of Fir			Principal Rafters of Oak			Principal Rafters of Fir			Principal Rafters of Oak		
	Scantling			Scantling			Scantling			Scantling	
Length	Top	Bottom	Length	Top	Bottom	Length	Top	Bottom	Length	Top	Bottom
if 24 ft.	5 in. & 6	6 in. & 7	if 24 ft.	7 in. & 8	8 in. & 9	if 24 ft.	7 in. & 8	8 in. & 9	if 24 ft.	8 in & 9	9 in. & 10
36	6½ 8	8 10	36	8 9	9 10½	36	8 9	9 10½	36	9 10	10 12
48	8 10	10 12	48	9 10	10 12	48	9 10	10 12	48	10 12	12 14

Although

"Although this table seems so plain as to need no explanation, it may not be amiss to observe some particulars, such as that all binding or strong joists, ought to be half as thick again as common joists; that is, if a common joist be given three inches thick, a binding-joist should be four inches and a half thick, although the same depth.

"Observe also, that if conveniency do not allow of posts in partitions being square, in such cases multiply the square of the side of the posts, as here given, by itself: for instance, if it be six inches square, then as six times six is thirty-six, consequently to keep this post nearly to the same strength, find some number that shall agree thereto; as suppose the partition to be four inches thick, then let your post be nine inches the other way, so that nine times four is thirty-six, being the same as six times six; so that the strength is nearly the same, although being equal in its squares is best for the strength.

"Posts that go the height of two or three stories, need not hold this proportion, because at every floor it will meet with a tie; admit a post was required of thirty feet high, and in this height there were three stories; two of ten feet, and one of eight. Look for posts of fir of ten feet high, their scantling is five inches square, *i. e.* twenty-five square inches; which double for the two stories.

"And take also that of eight feet high, being four inches square, *i. e.* sixteen square inches, all which being added together, make sixty-four square inches; so that such a post would be eight inches square. On occasion it may be lessened in each story as it rises.

"I do not insist that the scantlings of timber ought to be exactly as by this table is expressed, but may be varied in some respects, as the workmen shall see fit; the reason of its being inserted is in consideration of the scantlings of timber, as formally settled by Act of Parliament, and which, if compared, will prove the necessity and use of this table.

"As to plates on walls, or bressummers to support walls, I do not find they can come into any regular proportion, as the rest do, therefore must be left to discretion."

In Mr. Langley's publications, many interesting particulars are to be found relating to carpentry. Concerning partitions, he offers the following remarks in his *Builder's Complete Assistant*.

"When partitions have solid bearings throughout their whole extent, they have no need to be trussed; but when they can be supported but in some particular places, then they require to be trussed in such a manner, that the whole weight shall rest perpendicularly upon the places appointed for their support, and no where else. Partitions are made of different heights to carry one, two, or more floors, as the kinds of buildings require.

"The first things to be considered in works of this kind, are, the weight that is to be supported; the goodness and kind of timber that is to be employed; and proper scantlings necessary for that purpose.

"The strength of timber in general is always in proportion to the quantity of solid matter it contains. The quantity of solid matter in timber is always more or less, as the timber is more or less heavy; hence it is, that all heavy woods, as oak, box, mahogany, lignum-vitæ, &c. are stronger than elder, deal, sycamore, &c. which are lighter or (rather) less heavy; and, indeed, for the same reason, iron is not so strong as steel; which is heavier than iron; and steel is not so strong as brass or copper, which are both heavier than steel. To prove this, make two equal cubes of any two kinds of timber, suppose the one of fir, the other of oak; weigh them singly, and note their respective weights; this done, prepare two pieces of the same timbers, of equal lengths, suppose each five feet in length, and let each be tried up as nearly square as can be, but to such scantlings, that the weight of a piece of oak may be to the weight of a piece of fir, as the cube of oak, is to the cube of fir; then those two pieces being laid horizontally hollow, with equal bearings, and being loaded in their middles with increased equal weights, it will be seen that they will bend or sag equally; which is a demonstration that their strengths are to each other as the quantity of solid matter contained in them."

(Mr. Langley is here evidently wrong, for the relation between weight and strength is not general. In some cases the very reverse takes place to what he asserts.)

"As the whole weight on partitions is supported by the principal post, their scantlings must be first considered, and which should be done in two different manners, viz. first, when the quarters, commonly called studs, are to be filled with brick-work, and rendered thereon; and, lastly, when to be lathed and plastered on both sides.

"When the quarters are to be filled between with brickwork, the thickness of the principal posts should be as much less than the breadth of a brick, as twice the thickness of a lath; so that when these posts are lathed to hold on the rendering, the laths on both sides may be flush with the surfaces of the brickwork. And to give these posts a sufficient strength, their breadth must be increased at discretion; but when the quarters are to be lathed on both sides, or when wainscotting is to be placed against the partitioning, then the thickness of the posts may be made greater at pleasure. The usual scantlings for the principal posts of fir, of 8 feet in height, is 4 or 5 inches square; of 10 feet in height, 5 or 6 inches square; of 12 feet in height, 6 or 7 inches square; of 14 feet in height, 7 or 8 inches square; of 16 feet in height, from 9 to 10 inches square. But these last,

last, in my opinion, are full large, where no very great weight is to be supported. As oak is much stronger than fir, the scantling of oak posts need not be so large as those of fir; and therefore the scantlings assigned by Mr. Price, in his *Treatise of Carpentry*, are absurd, as being much larger than those he has assigned for fir roofs. To find the just scantling of oaken posts, that shall have the same strength of any given fir posts, this is the rule:

"As the weight of a cube of fir is to the weight of a cube of oak, of the same magnitude, so is the area of the square end of any fir post to the area of the end of an oaken post, and whose square root is equal to the side of the oaken post required."

(This assertion is obviously incorrect, and almost refutes itself.)

"The distances of principal posts are generally about ten feet, and of the quarters about fourteen inches; but when they are to be lathed on both sides, the distances of the quarters should be such as will be agreeable to the lengths of the laths, otherwise there will be a great waste in the laths. The thicknesses of ground-plates and risings, are generally from two inches and a half to four inches, and are scarfed together.

"For the better disposing of the weight imposed on girders, lintels should always be firmly bedded on a sufficient number of short pieces of oak, laid across the walls, vulgarly called *templets*, which are of excellent use.

"Let girders be laid in piers, or in lintels over windows; it will in both these cases be commendable to turn small arches over their ends, that in case their ends are first decayed, they may be renewed at pleasure, without disturbing any part of the brick-work; and for their preservation, anoint their ends with melted pitch and grease, viz. of pitch four of grease one; and, indeed, were lintels to be covered with pitch and grease also, it would contribute very greatly to their duration.

"In the carrying up the several walls of buildings, it should be carefully observed, to lay in bond-timbers on templets, as aforesaid, at every six or seven feet in height, cogged down, and braced together with diagonal pieces at every angle, which will bind the whole together in the most substantial manner, and prevent fractures by unequal settlement.

"The distances of girders should never exceed twelve feet, and their scantlings must be proportioned according to their lengths; as by experience it is known that a scantling of 11 inches by 8 inches, is sufficient for a fir girder of 10 feet in length, the area of whose end is 88 inches, it is very easy to find the proper scantling for a girder of any greater length, suppose 20 feet, by this rule; as 10 feet, the length of the first girder, is to 88 feet, the area of its end, so is 20 feet, the length of the second girder, to 176, the area of its end.

"Now to find its scantling, that, being multiplied into each other, shall produce 176 inches, the area found, one of them must be given, viz. either the depth or thickness. In this example, the given depth shall be 12 inches, therefore divide 176 by 12, and the quotient is 14 inches and two-thirds, which is the other scantling, or breadth required."

"To prevent the sagging of short girders, it is usual to cut them camber: that is, to cut them with an angle in the midst of their lengths, so that their middles shall rise above the level of their ends, as many half inches as the girder contains times ten feet. And, indeed, girders of the greatest length, although trussed, should be cut camber in the same manner."

It may be proper here to notice, that the cambering of girders does not prevent them from sagging, though perhaps it may obviate their becoming concave on the upper side. With regard to trussing girders, the flitches should not be cut to a camber, but brought into this state in the act of trussing.

"The next order is joists, of which there are five kinds, viz. common-joists, binding-joists, trimming-joists, bridging-joists, and ceiling-joists. First, common-joists are used in ordinary buildings, whose scantlings in fir are generally made as follows, viz.—

Common joists, as used in small buildings.			
Length in feet	Scantling in inches		
6	$6\frac{1}{4}$	×	$2\frac{1}{2}$
9	$6\frac{1}{4}$	×	$2\frac{1}{2}$
12	8	×	$2\frac{1}{2}$

(In looking at the table, it will naturally be asked why should the scantling of the joist 9 feet in length, be no more than of 6 feet? This must be a mistake.)

"But in large buildings, the scantlings are much larger, where it is common to make joists of the following dimensions:—

Common joists, as employed in large buildings			
Length in feet	Scantling in inches		
6	5	×	3
9	$7\frac{1}{2}$	×	3
12	10	×	3

"As oak is much heavier than fir, it is customary to make the scantlings of oak joists larger than those of fir; but I believe it to be entirely wrong, for

for the reason before given, relating to the strength of timber.

"Secondly, binding-joists are generally made half as thick again, as common joists of the same lengths;" and "are framed flush with the under surface of the girders, to receive the ceiling joists, and about 3 or 4 inches below their upper surfaces, to receive the bridging-joists; so that the upper surfaces of the bridging-joists may be exactly flush, or level, with the girder, to receive the boarding.

"The distances that binding-joists should be laid at, should not exceed 6 feet, though some lay them at greater distances, which is not so well, because the bridging, and ceiling-joists, must be made of larger scantlings, to carry the weight of the ceiling and boarding, and consequently a greater quantity of timber must be employed. But, however, as this particular is at the will of the carpenter, I shall only add that the scantlings for bridgings of fir," to their several lengths, are as follow:—

Bridgings of Fir.			
Bearing.	Scantling.		
feet	inches	by	inches
6	4	×	3
8	5	×	3
10	7	×	3

"Their distances from each other, about 12 or 14 inches."

He then goes to the subject of roofs.

"As the common method of framing the trusses of principal rafters of large roofs, is to lay the whole weight of the beam and covering upon the feet, they therefore should be secured at the beam with iron straps, to prevent their flying out, in case that the tenons should fail; but as I apprehend this method was capable of improvement, I therefore considered that if under the lower parts of principal rafters, there be discharging struts framed into the beams and pricked posts, they will discharge the principal rafters from the greatest part of the whole weight."

"This is an improvement, but the idea seems to have originated with Price and is to be found among his designs of roofs. It certainly gives an additional security to the principal rafters, so that if the outer abutment should fail, the roof will still be supported by the inner one.

His scantlings of fir timbers for roofs are as follows.

Beams			
Length	Scantling		
feet	inches	by	inches
30	6	×	7
45	9	×	7
60	10	×	8¼
75	10½	×	10
90	12	×	10½

Principal Rafters						
Length	Scantling at top			Scantling at Botm.		
feet	inches	by	inches	inches	by	inches
24	5	×	6	7	×	6
36	7	×	6	9	×	7
41	9	×	7	10	×	7½
60	10	×	7½	10	×	9
72	10	×	9	11	×	9½

Small Rafters			
Length	Scantling		
feet	inches	by	inches
8	4½	×	3
10	5	×	3
12	6	×	3

Mr. Langley in the same work gives examples of floors, made of short lengths, for the diversion of the curious; plans of various scarfings, and laying out of roofs in ledgement; with methods of tracing angle brackets, and covering niches or domes. He speaks also, of straight, circular, and elliptical arches in circular walls.

The Builder's and Workman's Treasury of Designs, by the same author, contains an appendix and fourteen plates, illustrative of carpentry.

In *The London Art of Building*, written by Salmon, there is nothing original. His principals of roofing are similar to those of Godfrey Richards, Independently of these he gives only a few designs of roofs.

In *The British Architect*, the production of Mr. Abraham Swan, there is nothing either very original and his constructions of carpentry are but scanty.

From the designs in Carpentry given by Mr. Isaac

Isaac Ware in his *Complete Body of Architecture*, and accompanying observations, we shall select a few, for the information of our readers.

"*Figures* 1 *and* 2, *Plate* 13.—Shews how plates laid on walls are joined together.

"*Figure* 3, The manner of putting beams together of three pieces, where extraordinary lengths are required. These will be equally strong as if they were of one piece of timber. A, shews the three pieces laid down and struck out; the scarf or lap is supposed to be 10 feet, divided into 6 lengths of tables; the hatched ones are sunk an inch or more, and when turned up, one will fit into the other with great exactness, which must be bolted together as in letter B."

"*Figure* 4, Is the upper face of a truss beam, where C, D, is 1-third of its length; it is mortised at D, four inches down; and as deep as C, as the templet on which it lies; this must be headed with a right butment, that is, square with the top or bottom of the braces. It is supposed to span 40 feet.

"E, upright of the said beam, with the disposition of its braces.

"*Figure* 5, Another kind of truss of the same length, 40 feet between wall and wall.

"F, Is a short beam 13 feet 4 inches, and placed on the back of the long beam G. The side braces will be about 13 feet 4 inches long, 6 inches by 4 inches square, with iron straps to clasp them and the upper beam, which is to be bolted to the lower beam G. The upper beam F, will be 12 inches by 10 inches square, which receive the ends of the binding joists in the middle; and those on each side, will lie upon the under beam G. 12 inches, by 12 inches square, the upper binding joists to be 4 inches by 7 inches, the under ones 6 inches by 4 inches square, the ceiling joists 3 inches by 2 inches.

"Note, the iron straps must be so ordered that they come not foul with the binding joists."

"*Figure* 6, exhibits a large truss roof which spans 60 feet between wall and wall, the principles of it are taken from a bridge in Palladio's 3rd, book of architecture, chap. 7.

The beam H, 65 feet long, may be made of 3 lengths of timber put together, as before decribed, and the following scantlings will be sufficient. viz.

	In		In	
H. Beam	12	by	8	square.
I. I. Principal rafters	10		8	
K. Middle king post	10		8	
L. L. Side king post	10		8	
M. M. The under rafters to the principles	8		8	
N. N. Braces	8		8	
O. O. Level rafters on which boarding is nailed to receive slating	6		3½	

"This roof is framed in an uncommon way, the tenons being made in the head of the king post, and the mortises in the head of the principal rafters, as is shewn more at large in *Figure* 14. The tenons may be about an inch thick, made in the middle, which will admit of strong butment cheeks on each side.

"*Figure* 7, is framed after the common manner, except the crown piece."

"*Figure* 8, shews a truss which spans 44 feet, and whose perpendicular length is equal to ¼ part of the beam.

	In		In	
A. the beam	10	by	8	square.
B. King post	10		8	
C. Principal rafters	10		8	
D. Braces	8		6	
Small rafters	5		3½	

"*Figure* 9, is a truss whose perpendicular height is equal to half the length of the beam, 22 feet, and which is framed with purlins for the small rafters to go downward, in order to receive laths for laying tiles on.

	In.		In.
The Beam E, 44 feet long, is	10	by	8
F and G principal rafters and king post	10		8
H. H. H. H. The purlins	8		6

"The lower purlins must be framed in flush with the upper side of the principal rafter, and the upper one framed 3 inches below, for the upper small rafters to lie upon it, which small rafters are 4 inches by 3 inches square, and the under one 5 inches by 3 inches; and this is called the common pitch of roofs.

"*Figure* 10, is a truss of 54 feet span, whose sides or principal rafters are made to the common pitch; and for the conveniency of gaining room in the garrets, it is finished with three small roofs."

"*Figure* 11, is the same kind of truss, leaving out the three small roofs, and making the top a flat on which a ballustrade may be placed, or a breastwork raised as in the figure."

He next shews a kind of trusses peculiarly adapted for the roofs of churches.

"*Figure* 12, is the most uncommon and best; this is framed in the manner described at large, in the third figure underneath it.

The scantlings sufficient for this truss are:—

	In.		In.	
A. The upper beam	12	by	8	square.
B. B. Principal rafters	10		8	
C. C. Lower beams	10		8	
D. D. Truss braces from the lower beam to the upper beam	10		8	
E. King post	10		8	
F. Braces to the king post	8		8	
G. Middle rib for the compass ceiling, to be in four parts	8		6	
H. H. The side ribs, ditto	8		6	
I. I. Puncheons on the top of the columns	10		8	

K, K,

	In.	In.
K. K. Truss braces to the middle rib	6	6
L. L. Braces to the side ribs	6	6

SCANTLINGS TO THE 13th, FIGURE.

A. The beam	12 by	9 square.
B. B. Puncheons on the top of the columns	12	9
C. C. Principal rafters	12	9
D. King post	12	9
E. E. Braces	6	6
F. F. Under short beam	12	9
G. G. Braces to it	8	8

" *Figure* 14, explains the manner of framing truss roofs two different ways; one side shews the king post A, whose scantlings are 10 inches by 8 inches square; this has a 4 inch mortise at B, which receives the 4 inch tenon, letter C, the head of the principal rafter, D, the beam has a like mortise at E, which receives the tenon F, which is the foot of the principal rafter G. The other side of the king post A, has an inch and quarter tenon in the middle of its thickness, as at H, made fit to receive the mortise I, in the head of the principal rafter. The like tenon is made at the other end of the beam D, as at K, and there is a mortise in the foot of the rafter L, to clasp the same."

" In this method of framing, which is quite uncommon, care must be taken that it be done with great exactness, that the butments may be good."

" As there are various proportions for the pitch of roofs, we have here inserted the several degrees that are most useful, from the pediment pitch to that of the equilateral triangle, called the pinnacle and described by *Figure* 15, (in which,)

A. is the pediment pitch.
B. rises ¼ the length of its base line.
C. rises equal to one half.
D. is the medium between that and the pediment.
E. is its height given by the length of the rafter, equal to ¾ of its base line.
F. the equilateral triangle.

" There is no article in the whole compass of the architect's employment, that is more important, or more worthy of a distinct consideration, than the roof; and there is this satisfaction for the mind of the man of genius in that profession, that there is no part in which is greater room for improvement."

" In order to understand, rightly, in what manner to undertake such improvement, he must first comprehend perfectly the idea and intent of this part of a building, and what is generally known concerning its structure."

" The great caution is, that the roof be neither too massy nor too slight: in the one case, it will be too heavy, and in the other to light for the house. Both extremes are to be avoided, for in architecture every extreme is to be shunned; but of the two, the over weight of roof is more to be regarded than too much slightness. This part is intended not only to cover the building, but to press upon the walls, and by that bearing, to unite and hold all together. This, it will not be massy enough to perform, if too little timber be employed, so that extreme is to be shunned; but, in practice, the great and common error is on the other side; and he will do the most acceptable service to his profession, who shall shew how to retrench, and execute the same roof, with a smaller quantity of timber; he will by this, take off an unnecessary load from the walls, and a large and useless expence to the owner."

" The roof of a house properly expresses the frame of wood-work which is raised upon the walls, and the covering of slate, tile, or lead, which is laid over it; and thus, the architect is to understand it, for he is to compute its weight entire, when he considers the proportion of its pressure, to the supports; but, in the common manner of speaking, only the carpentry or timber work is understood, under this term."

" The forms of a roof may be various. The three principal kinds are, the flat, the square, and the pointed; to these we are to add the pinnacle roof, the double ridged, and the mutilated roof. This last is very beautiful, and is called the mansard roof, after the name of a French architect, its inventor. Lastly, we are to name the platform, and truncated roofs, and adding to all these, the dome, we shall have the list of the principal kinds. We might add, the ogee roof, which is a piece of French architecture, neither commodious, nor graceful; and some others, which fancy often prefers to better kinds, but of these we shall treat more largely hereafter, the intent in this place being to give a general idea of the roof, its nature, proper weight, and proportion."

" When the roof is pointed, its best proportion is to have the profile an equilateral triangle. In the square roof, the angle of the ridge is a right angle; this, therefore, is a middle proportion, between the pointed, and the flat roof, which is in the same proportion as a triangular pediment, The pinnacle roof has its name from its form, being carried up in resemblance of a pinnacle. The mansard consists of a true and a false one; the false roof lying over the true. The platform roof, is common in the East, and the truncated kind approaches to the nature of it. This is cut off at a certain height, instead of rising to a ridge, and this part is covered sometimes with a terrace, and encompassed with a balustrade. Of the dome we shall speak in its place, and of the other species of roofs. This account is sufficient for the general idea of the nature, and form, of this part of an edifice."

" Whatever be the form of the roof, the architect must take care in the construction to preserve its weight equally on the separate parts, that it may not bear more upon one side of the building than another

another, and in the construction of the whole edifice, he will do well to contrive, that the inner walls bear their share of the load, that more than is needful be not laid upon the outer ones."

"The roof surrounding every part of the building, and pressing equally upon every part, becomes what it was intended, a band of union and firmness, as well as a covering to the whole. It preserves the walls also, by throwing the rain off from them. The making the middle or inside walls assist in supporting the roof, is best done by making them support the girders, and this has many ways an excellent effect: for a roof in this case, is not in danger of falling from the rotting of the end of a girder, which is otherwise very often, either entirely destructive to this part, or at least an inconvenience very difficult to be supplied."

Concerning floors he says: "We have reserved the mentioning of floors, till we had considered the walls and the roof of the edifice, because they are introduced in this order in the building of a house; the practice being not to lay them till the house is enclosed and covered in, because otherwise they would be injured by the weather. We are to advise the young architect to get the boards ready long before, because although they are not to be used for a considerable time, it will be of great advantage to let them stand to season. As soon, therefore, as the plan of the building is laid, and the dimensions of the several rooms allotted, let the boards for the floor be cut and rough-planed; then being carefully put by, in a dry airy place, they will be in a good measure seasoned by the time they are put to use."

"The floors of all the rooms upon the same story, and of all the passages between them, should be perfectly even: not so much as a threshold should be suffered to rise above the level of the rest; and if in any part there be a room or closet whose floor is lower than the general surface, it should not be left so, but raised to the level of the rest, what is wanting being supplied by a false one."

"We have hitherto spoke of timber floors, by which name is properly expressed nothing more than the covering of boards on which we tread; but in the usual acceptation it stands for the whole body of the work in this part; comprehending the framed work of timber which supports the boards, as well as the covering itself which is fixed upon it. But beside these, which are the most general, and as it were universal floors of common houses about London, there are several other kinds used in country buildings, and by some in the most elegant and highly finished."

The next author is Mr. William Pain; but his works having been already enumerated, we shall pass on to the "*The Carpenter's New Guide*, by Mr. Peter Nicholson, the last edition of which was printed in 1808.

Mr. Nicholson in his preface, observes "that whatever rules by previous authors have on examination proved to be true and well explained, these have been selected and adopted, with such alterations as a very close attention has warranted for the more easily comprehending them, for their greater accuracy or facility of application: added to these, are many examples which are entirely of my own invention, and such as will, I am persuaded, conduce very much to the accuracy of the work and to the ease of the workman."

He commences his works with an introduction to practical geometry, and then proceeds to the consideration of groins "for the construction of which (he says) "there will be found many methods entirely new; and besides the common figures, I have shewn many which are difficult of construction, and not to be found in any other author. I have displayed a large assortment of niches of each kind; these are frequently wanted, those of the elliptic form only have yet been explained: in addition to these, there will be found schemes for globular ones, which occur frequently in practice."

The next object of his attention, is the finding of various lines for roofs, and on this subject he points out an entirely new plan of finding the down and side bevels of purlines, so as to make them fit exactly against the hip rafter, by the same method the jack rafter will be made to fit.

Speaking of domes and polygons, he details an original method of finding their covering, within the space of the board; with a method also of finding the form of the boards near the bottom, when a dome is required to be covered horizontally. A true rule is likewise given for finding the proper curve of dome lights over stair-cases, against the wall, and the curve of the ribs.

This ingenious author, very properly observes in his preface "by way of caution and guard to the ardent theorist, that there are on some surfaces curve lines, which cannot be found absolutely true to one another; such as spherical or spheroidical domes, where their coverings cannot be found by any other means, than by supposing them to become polygonal; in which case they may be performed upon true principles, as may be demonstrated.—Let us suppose a polygonal dome inscribed in a spherical one; then, the greater the number of sides of the polygonal dome, the nearer it will coincide with its circumscribing spherical one.—Again, let us suppose that this polygon has an infinite number of sides; then, its surface will exactly coincide with the spherical dome, and therefore in any thing which we shall have occasion to practise, this method will be sufficiently near; as for example, in a dome of one hundred sides, of a foot each, the rule for finding such a covering will give the practice so very near, that the variation from absolute truth could not be perceived."

He

He next proceeds to the practical part of Carpentry, in which a great variety of designs are given for floors, trusses, girders, roofs, domes, and partitions, on new and approved principles. Some of his remarks on these subjects deserve attention.

"In that nice and elegant branch of the Building Art called joinery, stairs, and hand-rails take the lead; and notwithstanding the great importance of this subject, I am sorry to find it has been treated, by authors in general, in a very clumsy and slovenly manner. For stair-cases, in general, I have laid down right methods, on principles entirely new, and which, since the publication of the former edition of this work, I have the satisfaction to say, have been put in practice, and found to answer well."

"Various methods for diminishing columns are shewn, together with two new ones, which I flatter myself are more easily adapted to practice. Among other things of inferior note, is a method for finding the lines of a circular sash in a circular wall; also, a method, to the same purpose, for architraves in a circular wall; neither of which have before been given or explained. For mitring raking mouldings, I have, with some pains, confirmed a true method, not merely in theory, but by models, which I have by me, and am willing to show at convenient seasons, to any inquirer."

"I must not here omit to observe, for though last, not least, that my speculations and calculation on the strength of timber, will, I hope, be found particularly useful; and not merely so, but may also tend to induce others to consider this subject, whose leisure and abilities may lead to more important discoveries; I beg leave to add, that, to confirm the mathematical calculations, I have tried several of the questions by experiments. He who is a perfect master of this branch, may err in decoration, but never can in strength and proportion."

Speaking of its conclusion, he says;

"It is intended to guard the young and incautious student against error; for wrong maxims are with more difficulty obliterated from the mind, than originally obtained."

The Carpenter's and Joiner's Assistant, by the same author, is a work replete with useful information. He begins with observations on soffits, and then proceeds to notice groins, niches, and pendentives. In adverting to these subjects, he gives some examples for constructing naked floors, in the best possible manner, which he illustrates by explanations of the various parts; to which are added, examples for framing of partitions, and some new plans of roofing, &c. This part of the work contains some designs of celebrated roofs, constructed agreeably to the several dimensions of the various scantlings, and concludes with remarks on mortises, tenons, king posts, &c.

He next considers that very useful subject, the strength of timber, and then proceeds to joinery; wherein he offers several new inventions.

The same author's *Treatise on Carpentry*, in his *Mechanical Exercises*, is entitled to considerable attention.

We have now taken a view of the several publications on Carpentry, which will enable the observing student, we conceive, to judge of the progress that has taken place in the art, from Godfrey Richards, our earliest writer, to Mr. Peter Nicholson, the latest. The works of the latter have strong claims, and may be confidently recommended to the notice of all, who wish to excel in this particular department. It is greatly to be wished, that Mr. Nicholson would continue to pursue his scientific researches into this noble art, with that ardour for which he is so eminently distinguished. We have no doubt, much as it has been already improved, that it is still susceptible of improvement, and that many discoveries equally entitled to admiration, as his former ingenious inventions, would reward his trouble, and render him a still greater ornament to his profession. It is but justice, however, to the other authors to remark, that if in the several extracts we have selected from them, there be little embellishment of language, and indeed some inaccuracies of expression, yet there are evident proofs in them, of sound, natural sense, and mature reflection, and to them, every discerning mind will readily concede their due weight and consequence.

THIRD DIVISION.

Strength of Materials.

Strength, denotes that particular force or power, with which any mass or body resists a breach or change in its state, endeavoured to be produced by a stroke or pressure.

Stress or Strain, may be defined as the force exerted upon a body in order to break it.

Thus, every part of a pillar is equally strained by the load which it sustains; and it is evident that no structure can be considered fit for its purpose, unless the strength prevailing in all its parts, be at least equal to the stress laid on, or the strain excited in those parts; from hence may be perceived the necessity of becoming acquainted with the nature of the resistance made by various bodies, since it will teach us to proportion the materials in a machine or structure of any kind, so as that there shall be neither a surplus nor a deficiency.

It has been justly observed by an excellent writer, "that in a nation so eminent as this for invention and ingenuity in all species of manufactures, and in particular, so distinguished for its improvements in machinery of every kind, it is somewhat singular that no writer has treated it in the detail, which its importance and difficulty demands. The man of science who visits our great manufactories, is delight-

ed with the ingenuity which he observes in every part, the innumerable inventions which come from individual artisans, and the determined purpose of improvement and refinement which he sees in every workshop. Every cotton mill appears an academy of mechanical science; and mechanical invention is spreading from these fountains over the whole kingdom. But the philosopher is mortified to see this ardent spirit so cramped by ignorance of principle; and many of these original and brilliant thoughts, obscured and clogged with needless and even hurtful additions, and a complication of machinery which checks improvement by its appearance of ingenuity. There is nothing in which this want of scientific education, this ignorance of principle, is so frequently observed, as in the injudicious proportion of the parts of machines and other mechanical structures; proportions and forms of parts in which the strength of position are nowise regulated by the strains to which they are exposed, and where repeated failures have been the only lessons."

"It cannot be otherwise" the same author continues "We have no means of instruction, except two very short and abstracted treatises of the late Mr. Emerson, on the strength of materials. We do not recollect a performance in our language from which our artists can get information. Treatises written expressly on different branches of mechanical arts, are totally silent on this which, is the basis and only principle of their performances. Who would imagine that *Price's British Carpenter*, the work of the first reputation in this country, and of which the sole aim is to teach the carpenter to erect solid and durable structures; does not contain one proposition, or one reason, by which one form of a thing can be shewn to be stronger or weaker than another? We doubt very much if one carpenter in a hundred can give a reason to convince his own mind, that a joist is stronger when laid on its edge, than when laid on its broad side. We speak in this strong manner, in hopes of exciting some man of science to publish a system of instruction on this subject."

The strength of materials arises immediately, or ultimately, from the attraction of cohesion which is observable in almost every natural object, and is, in reality, that which holds their component parts together.

Now as cohesion admits of various modifications in its different appearances of perfect softness, elasticity, hardness &c. and has a great influence on the strength of bodies, it will by no means admit of the application of mathematical calculations, with that precision and certain success, which are desirable in a point of so much importance.

The texture of materials is a subject of no less importance, and experiments in this respect, have been made by Couplet, De la Hire, Pitot, and Du Hamel: but the same remark is applicable to them, as to the experiments on the cohesion of bodies, and, consequently being so limited, that information is not to be obtained from them which we could wish. Buffon, however, carried on some experiments on a more extensive and proportionately useful scale, and from him only are to be obtained those measures, which may be relied on with safety and success.

Our countrymen Emerson, and Banks, have it is true, made several experiments on the strength of bodies, but their researches too have been so limited and imperfect, as to preclude the student from placing any particular confidence in their results.

It may not be irrelevant to observe here, that experiments may be considered as nothing less than a narration of certain detached facts, if some general principles are not established, by which we can generalise their results.

Some idea, for instance, may be entertained of that medium or cause, by the intervention of which, an external force applied to one part of a lever, joist, or pillar, occasions a strain on a distant part. This can be nothing more or less than the cohesion existing between the parts which are brought into action, or as we more shortly express it, excited. In order properly to comprehend the nature of cohesion, it will be necessary to take a view of its laws, or rather of those general facts which are observable in its operations. In doing this, however, it will be sufficient to notice such general laws only, as seem to present the most immediate information of the circumstances required to be attended to by mechanics in general, if they would wish to unite strength with simplicity and economy, in their several constructions.

1st. We have presumptive evidence to prove, that all bodies are elastic in a certain degree, that is when their form or bulk is changed by *certain moderate* compressions, it requires the continuance of the force producing the change, in order to continue the body in its altered state, and when the compressing force is removed, the body recovers its original form and tension.

2d. That whatever may be the situation of the particles composing a body, with respect to each other when in a state of quiescence, they are kept in their respective places, by the balance of opposing forces.

3d. It is an established matter of fact, that every body has some degree of compressibility, as well as of dilatability: and when the changes produced in its dimensions are so moderate, that the body compleatly recovers its original form on the cessation of the changing force, the extensions or compressions, bear a sensible proportion to the extending, or compressing forces; and, therefore, the connecting forces are proportioned to the distance, at which the particles are diverted, or separated, from their usual state of quiescence.

4th.

4th. It is universally observable, that when the dilatations have proceeded to a certain length, a less addition of force is afterwards sufficient to increase the dilatation in the same degree. For instance, when a pillar of wood is overloaded, it swells out, and small crevices appear in the direction of the fibres. After this, it will not bear half of the previous load.

5th, That the forces connecting the particles composing tangible or solid bodies, are altered by a variation of distance, not only in degree, but also in kind.

Having now enumerated the principal modes, in which cohesion confers strength on solid bodies, we proceed to consider the strains to which this strength may be opposed.

These strains are four in number, viz.—

1st. A piece of matter may be torn asunder, as is the case with ropes, king posts, tie beams, stretchers, &c. &c.

2d. It may be crushed, as is the case with pillars, truss beams, &c. &c.

3d. It may be broken across, as happens to a joist or lever of any kind, or

4th. It may be wrenched or twisted, as is the case with the axle of a wheel, the nail of a press, &c. &c.

With respect to the first strain, it may be observed, that it is the simplest of all strains, and that the others are but modifications of it; it being directly opposed to the force of cohesion, without much being influenced, except in a slight degree in its action, by any particular circumstances. When a prismatic, or cylindrical body of considerable length, such as a rope, or a rod of wood, or metal, has any force exerted on one of its ends, it will naturally be resisted by the other, from the effect or operation of cohesion. When this body is fastened at one end, we may conceive all its parts to be in a similar state of tension, since all experiments on natural bodies concur to prove, that the forces which connect their particles, in any way whatever, are equal and opposite.

Since all parts are thus equally stretched, it follows, that the strain in any transverse section, as well as in every point of that section is the same. If then, the body be of any homogeneous texture, the cohesion of the parts is equable, and from every part being equally stretched, the particles are diverted or separated from their usual state of quiescence, to equal distances; of course the connecting powers of cohesion thus excited, and now exerted in opposition to the straining force, are also equal. It is evident, therefore, that this external force may be increased by degrees, so as gradually to separate the parts composing the body, more and more from each other, and that the connecting forces of cohesion, will bear a relative proportion to the increase of distance, till finally some particles weaken: then the rest are overcome by the pressure or tension, when a fracture ensues, and the body itself is soon crushed, or broken in all its parts. If the external force be insufficient to produce any permanent change on the body, and that body recovers its former dimensions, when the operating force is withdrawn, it is clear that this strain may be repeated, whenever desired, and that the body which has withstood it once, will always be equal to the task of withstanding it. This circumstance should not only be attended to in constructions of every kind, but kept constantly in view in every investigation of the subject.

Bodies of a fibrous texture, exhibit very great varieties in their modes of cohesion. In some, the fibres have no lateral connecting force, as in the case of a rope. The only way in which all the fibres composing a piece of matter can be made to unite their strength, is by twisting them together, which has the effect of bending each to each, so fast, that any one of them will rather break than be separated in a perfect state from the remainder. In timber, the fibres are held together by some glutinous cement, which is seldom however, as strong as the fibre, and for this reason timber is much easier pulled asunder when operated on in a direction transverse to the fibres; but, nevertheless, there is every possible variety in this particular.

In stretching and breaking fibrous bodies, though the visible extension is frequently very considerable, it does not solely arise from the increasing the distance of the particles composing the cohering fibre, but is chiefly occasioned by drawing the crooked fibre straight. In this respect a great diversity prevails, as well as in the powers required to withstand a strain. In some woods, such as fir, the fibres on which the strength most depends, are very straight, and woods of this nature, it should be remarked, are generally very elastic, and break abruptly when overstrained; others, as oak, have their resisting fibres very crooked, and stretch very sensibly when subjected to a strain. These kinds of woods do not break so suddenly, but exhibit visible signs of a derangement of texture.

The absolute attraction of cohesion, or strength, is proportioned to the area of the section which stands at right angles with the extending force. This will be readily admitted in the case of fibrous bodies, if we suppose the fibres composing them to be equally strong and dense, and to be disposed similarly through the whole section; there is a necessity for admitting this, or else the diversity must be stated and the cohesion must be measured accordingly.

The following observation may be admitted as a general proposition in this respect; *the absolute strength in any part of a body, which enables it to resist being pulled asunder, or the force which must be employed to tear it asunder in that part, bears a proportion to the area of the section which stands*

stands at right angles with the extending force.

Hence, then, we may deduce that cylindrical and prismatic rods are equally strong in every part, and will break alike in any part, and that bodies formed into unequal sections, will always break in the most slender part. The length of the prism or cylinder produces no effect on the strength: and the vulgar notion that a long rope may be broken more easily than a short one, is altogether absurd.—It may be further observed, that the absolute strengths of bodies whose sections are similar to each other, bear a relative proportion to the squares of their diameters, or homologous sides of the section.

The weight of the body itself, may in some instances, be employed to strain and to break it; as is the case with a rope, which may be so long as to break by its own weight.—When the rope hangs in a perpendicular direction, although its strength is equal in every part, the fracture will take place towards the upper end, since the strain on any part is equal to the weight of all below it, or in other words, its relative strength in any part, or power of withstanding the strain to which it is subjected, is inversely as the quantity below that part.

When the rope is stretched horizontally, the strain arising from its weight, oftens bears a very sensible proportion to its whole strength.

Let A E B, *Figure* I, represent any portion of such a rope, in which case, the curve A E B, will be the catenaria; and if the tangents A C, B C, be drawn through the points of suspension, if the parallelogram A B C D, be compleated, and if the diagonal also D C, be drawn; D C will be to A C, as the weight of the rope A E B, is to the strain exerted at A, and the strain exerted at B, will be found by a similar process.

When a suspended body is required to be so strong throughout, as to carry its own weight in any part, the section in that part must be proportioned to the solid contents of all below it. If A a e, (*Figure* 2.) be supposed to represent a section of a conoidal spindle, we must have A C^2 : a c^2 :: A E B sol : a E b sol. The curve A a e, is known among mathematicians, by the name of the logarithmic curve, of which C c, is the axis.

These are the chief general rules, which can with safety be deduced from our clearest, though imperfect conceptions of the nature of that cohesion, which connects bodies together, and in order to make a practical use of these, it is necessary that we should be acquainted with those modes of ascertaining the attraction of cohesion in solid bodies, which are most commonly employed by practical mechanics.

As the cohesion of bodies of the same kind, are known to differ in innumerable circumstances, we will take for the measure of cohesion, the weight of pounds avoirdupoise, which suffice to tear asunder a rod, or bundle, of one inch square. From this, it will be easy to compute the strength, corresponding to any other dimensions.

With regard to the tenacity, or strength of wood:

1st. The wood which surrounds immediately the pith, or heart of the tree, is supposed to be the weakest, and this weakness is greater, as the tree is older. We give this as the result of experiments made by Muschenbroëk; but Buffon says, his experiments proved to him, that the heart of a sound tree is the strongest; for which assertion, however, he assigns no authority. It is certain, from accurate observations which have been made on very large oaks and firs, that the heart is much weaker than the exterior parts.

2d. The fibres next the bark, commonly called, the white or blea, are also weaker than the rest, and the wood gradually increases in strength, as it recedes from the centre to the blea.

3d. The wood is stronger in the middle of the trunk, than at the springing of the branches, or at the root: and the wood forming a branch, is weaker than that of the trunk.

4th. The wood on the northern side of all trees which grow in Europe, is the weakest, while that on the south-eastern side is the strongest, this difference is most remarkable in hedge row trees, and such as grow singly. The heart of a tree never lies in its centre, but always towards its northern side, and the annual coats of wood are thinner on that side.—In conformity with this, it is a general opinion of carpenters that timber is stronger in proportion to the thickness of its annual plates. The trachea, or air-vessels, being the same in diameter and number of rows, in trees of the same species, occasion the visible separation between the annual plates, for which reason when these are thicker, they contain a greater portion of the simple ligneous fibres.

5th. All woods are most tenacious while green: but after the trees are felled, that tenacity is considerably diminished by their drying.

Muschenbroëk is the only author who has given us an opportunity of judging minutely in this respect. The woods which he selected for experiment were all formed into slips, part of each of which was cut away to a parallelopiped, of 1-fifth of an inch square, and therefore 1-twenty-fifth of a square inch in section. The absolute strengths of a square inch, were as follows:—

	Pounds
Locust tree	20100
Jujeb	18500
Beech and oak	17300
Orange	15500
Alder	13900
Elm	13200
Mulberry	12500
Willow	12500
Ash	12000

Plum

	Pounds
Plum	11800
Elder	10000
Pomegranate	9750
Lemon	9250
Tamarind	8750
Fir	8330
Walnut	8130
Pitch pine	7650
Quince	6750
Cypress	6000
Poplar	5500
Cedar	4880

Muschenbroek, gives a very minute detail of his experiments on the ash and walnut, in which he states the weights required to tear asunder slips taken from the four sides of these trees, and on each side, in a regular progression from the centre to the circumference. The numbers in the foregoing table corresponding with these two woods may be considered, therefore, as the average of more than fifty trials of each. He mentions also that all the other numbers were calculated with the same care. For these reasons some confidence may be placed in the results; though they carry the degrees of tenacity considerably higher, than those enumerated by some other writers. Pitot and Parent observe, that a weight of sixty pounds will just tear asunder a square line of sound oak, but that it will bear fifty pounds with safety. This gives 8640 for the greatest strength of a square inch, which is much inferior to Muschenbroek's calculation. To the foregoing table may be added:—

	Pounds
Ivory	16270
Bone	5250
Horn	8750
Whalebone	7500
Tooth of sea calf	4075

These numbers express something more than the utmost attraction of cohesion, the weights are such as will very quickly, (that is in a minute or two,) tear the rods asunder. In general it may be observed, that two-thirds of these weights will greatly impair the strength after a considerable time, and that one half is the utmost that can remain suspended at them, without incurring the risk of their demolition; and on this calculation of one half of the nominal weight, the engineer should reckon in all his constructions; though, even in this respect, there are great shades of difference. Woods of a very straight fibre, such as fir, will suffer less injury from a load which is not sufficient to break them immediately.

Mr. Emerson mentions the following as the weights, or loads, which may be safely suspended to an inch square, of the several bodies hereafter enumerated.

	Pounds
Iron	76400
Brass	35600
Hempen Rope	19600
Ivory	15700
Oak, Box, Yew and Plum tree	7850
Elm, Ash, and Beech	6070
Walnut, and Plum	5360
Red fir, Holly, Elder, Plane, and Crab	5000
Cherry, and Hazel	4760
Alder, Asp, Birch, and Willow	4290
Lead	430
Freestone	914

This ingenious gentleman has laid down as a practical rule, that a cylinder whose diameter is d inches, will carry, when loaded to one fourth of its absolute strength, as follows.—

	Cwt.
Iron	135
Good rope	22
Oak	14
Fir	9

It is necessary to remark that the ranks which the different woods hold in Mr. Emerson's list, in point of tenacity, differs materially from those assigned to some of them by Muschenbroek.

Secondly we observe that bodies may be crushed.—It is an object of the first importance to ascertain the weight, pressure, or strain, which may be laid on solid bodies without the danger of crushing them. Posts and pillars of all kinds are exposed to this strain in its most simple form, and there are some cases where the strain is enormous, as, for instance, where it arises from the oblique position of the parts, which is the case with struts, braces, and trusses, and frequently occurs in our great works.

Some general knowledge of the principle which determines the strength of bodies in opposition to this strain, must be allowed to be desirable. Unfortunately we are much more at a loss in this respect, than in the preceeding.

It is the opinion of some eminent men, that the resistance which bodies are capable of making to an attempt to crush them, bears a proportion to the external force; for as each particle composing the body is similarly and equally acted upon, the aggregate resistance of that body, must correspond with the extent of the section.

This principle, however, is considered as ill founded, by others no less eminent for their scientific and experimental knowledge.

But as it must be acknowledged, that the relation existing between the dimensions and the strength of a pillar has not been established on solid mechanical

principles, and experience plainly contradicts the previous opinion, that the strength is proportional to the area of the section, it would appear that the required ratio depends much on the internal structure of the body, and experiment seems to be the only method of ascertaining the general laws of cohesion.

If a body be of a fibrous texture, with its fibres situated in the direction of the pressure, and slightly connected with each other by some kind of cement, such a body will fail only when the cement connecting them gives way, and they are detached from each other. Something like this may be observed in wooden pillars, in which it would appear, that the resistance must be as the number of equally resisting fibres, and as their mutual support jointly, or as some function of the area of the section. Precisely the same thing will happen, if the fibres are naturally crooked, provided some similarity in their form be supposed. We must imagine always that some similarity of kind exists, or otherwise it will be absurd to aim at any general inferences.

In all cases, therefore, we can hardly hesitate to admit, that the strength exerted in opposition to compression, bears a relative proportion to a certain function of the area of the section.

It does not appear that the strength of a pillar is at all affected by its length, as the whole length of a cylinder or prism is equally pressed. If, indeed, these bodies may be supposed to bend under the pressure, the case is materially altered, because, then, they are subject to the influence of a transverse strain, which, it is well known, increases with the length of the pillar. This, however, will be considered under the next class of strains.

Parent has shown that the force required to crush a body, is nearly equal to that which will tear it asunder. He observes, also, that it requires something more than sixty pounds on every square line, to crush a piece of sound oak; but this rule is by no means general. Glass, for instance, will carry a hundred times more on it than oak in this way, but will not bear suspended above four or five times as much. Oak will suspend a great deal more than fir, but fir will carry twice as much as a pillar. Woods of a soft texture, although they may be composed of very tenacious fibres, are more easily crushed by the load upon them. This softness of texture is chiefly owing to the crooked nature of their fibres, and to the existance of considerable vacuities between each fibre, so that they are more easily bent in a lateral direction and crushed. When a post is overstrained by its load, it is observed to swell sensibly in diameter.

In all cases where the fibres lye oblique to the strain, the strength is considerably diminished, which may be ascribed to the circumstance, that the parts in such case, slide on each other, and the connecting force of the cementing matter, is for that reason easier overcome.

Mr. Gauthey in the fourth volume of Rozier's *Journal de Physique*, published the result of some experiments which he had made on small rectangular parallelopipeds, cut from a great variety of stones.

The following table exhibits the medium results of several trials on two very similar sorts of freestone, one of which, was among the hardest, and the other among the softest kinds used in building. The first column expresses the length A B, of the section, in French lines, or 12ths of an inch: the second points out the breadth B C; the third shews the area of the section, in square lines; the fourth exhibits the number of ounces required to crush the piece; the fifth represents the weight then borne by each square line, or twelfth of an inch of the section; and the sixth displays the round numbers, to which Mr. Gauthey imagines that those in the fifth column approximate.

	AB	BC	AB×BC	Weight	Force	
			HARD STONE.			
1	8	8	64	736	11·5	12
2	8	12	96	2625	27·3	24
3	8	16	128	4496	35·1	36
			SOFT STONE.			
4	9	16	144	560	3·9	4
5	9	18	162	848	5·3	4·5
6	18	18	324	2928	9	9
7	18	24	432	5296	12·2	12

It may be proper to observe, that the first and third columns, compared with the fifth and sixth, ought to furnish similar results, because the first and fifth respectively form half of the third and sixth, but the third, it will be remarked, is three times stronger than the first, while the sixth is only twice as strong as the fifth. It is evident, however, that the strength increases in a much greater ratio than the area of the section, and that a square twelfth part of an inch, can carry more and more weight, in proportion to the increased dimensions of the section, of which it forms a part. In the series of experiments on the soft stone, the individual strength of a square line, seems to increase nearly in the proportion of the section of which it is a part. Mr. Gauthey, deduces from the whole of his numerous experiments, that a pillar, formed of hard stone from Givry, whose section is a square foot, will bear with perfect safety 664000 pounds, that its extreme strength is 871000, and that the most inferior instance of strength is 460000. The soft bed of Givry stone, had for its smallest strength, 187000, for its greatest 311000, and for its safe load 249000.

This gentleman's measure of the suspending strength of stone, is very small in proportion to its power of supporting a load laid above it.

He found that a prism, of the hard bed of Givry stone, the section of which was one foot, was liable

to be torn asunder, when subjected to a weight of 4600 pound, and when firmly fixed horizontally in a wall, that it was broken by a weight of 56000 pounds, suspended a foot from the wall. If the prism rests on two props, separated a foot from each other, it will be broken by 206000 lbs. when that weight operates, or is laid on its middle. These experiments differ so very widely from each other, in their several results, that they cannot be deemed of much advantage to us.

A judicious series of experiments on this most interesting subject, would be exceedingly valuable, and its usefulness cannot be too highly estimated. In the construction of wooden bridges, centers, &c. this species of strain, is very frequently found, and, therefore it is particularly entitled to the attention of the engineer. But how few engineers can find sufficient leisure in the hurried operations of their business, for prosecuting experiments with that coolness and patient investigation, which the subject demands? It is singular, that in an empire like this, and in a matter of such unquestionable importance, that some person of sufficient judgement and abilities, has not been appointed to institute the necessary enquiries, on an extensive and liberal scale, into the various strains to which materials in general are subject.

The only way in which we can effect any good, during the absence of these essential experiments, is by paying a careful attention to the manner in which fractures are produced. By attending to this, there may be some prospect of introducing a degree of accuracy, by mathematical measurement, which is an object "devoutly to be wished for," in matters of this kind.

BODIES MAY BE BROKEN ACROSS.

The strain which most commonly acts on materials of any nature, is that which tends to break them in a transverse direction. This species of strain, however, is but seldom effected, or rather tried in that simple manner which the subject apparently admits of; for when a beam projects horizontally from a wall, and a weight is suspended from its extremity, the beam is most commonly broken near the wall, in which case the intermediate part has performed the operation of a lever. It sometimes, though rarely happens, that the pin in the joint of a pair of pincers or scissars, is cut through by the strain; and this is almost the only instance of a simple transverse fracture. In consequence of its being so rare, we shall content ourselves with remarking, that in this case, the strength of the piece bears a proportion to the area of the section. Experiments have been made in the following manner, for discovering the resistances made by bodies to this species of strain. Two iron bars were disposed horizontally, at the distance of an inch from each other; a third bar was then hung perpendicularly between them, being supported by a pin made of the substance intended to be examined.

This pin was made in the shape of a prism, so as to acommodate itself to the holes in the three bars, which were made very exact, and of similar size and shape. A scale was next suspended at the lower end of the perpendicular bar, and loaded till it tore out that part of the pin which occupied the middle hole, which load was, evidently, the measure of the lateral cohesions of two sections. The side bars were made so as to grasp the middle bar pretty strongly between them, and that no distance might intervene between the conflicting pressures. This would have combined the energy of a lever, with the purely transverse pressure; for which reason it was necessary that the internal parts of the holes should not be smaller than the edges. Great irregularities occurred in the first experiments, in consequence of the pins being somewhat tighter within, than at the edges; but when this had been corrected, the trials became extremely regular. Three sets of holes were employed on this occasion; viz. a circle, a square, and an equilateral triangle, though the square was occasionally converted into a rectangle, the length of which was equal to twice its breadth. In all the experiments the strength was found to bear an exact proportion to the area of the section, to act perfectly independent of its figure or position, and to rise considerably above the direct cohesion; that is, it required the operation of considerably more than twice the force to tear out this middle piece, than to rend the pin asunder by a direct pull. A piece of fine free stone required 205 pounds to rend it directly asunder, while 575 were required to break it in this way. The difference was very constant in any one substance, but it varied from four thirds to six-thirds in bodies of different kinds, and was smallest in those of a fibrous texture.

But the more common case, where the energy of a lever intervenes, demands a strict consideration.

Let ABCD, *Fig.* 3, be supposed to represent the vertical section of a prismatic solid, projecting horizontally from a wall in which it is firmly fixed; and let a weight P, be hung on it at B, or let any power P, act at B, in a direction perpendicular to A B.—Let this body also be considered to possess insuperable strength in every part, except in the vertical section D A, perpendicular to its length, in which section only it must break.—Let the cohesion be uniform throughout the whole of this section; that is, let each of the adjoining particles of the two parts cohere with an equal force *f*. There are two ways in which it may then break. The part A B C D, may simply slide down along the surface of the fracture, provided the power acting at B, be equal to the accumulated force which is exerted by every particle, composing the section, in the direction A D. But let this be supposed as effectually prevented by something supporting the point

A

A. The action at P, tends to make the body turn round A (or round a horizontal line passing through A at right angles with A B) in the same manner as round a joint. This, it cannot do without separating at the line D A, in which case the adjoining particles at D, or at E, will be separated horizontally. But their attraction of cohesion resists this separation. In order, therefore, that the fracture may happen at the place intended, the energy of the power P, acting by means of the lever A B, must be superior to the accumulated energies of the component particles. The energy of each depends not only on its cohesive, or connecting force, but also on its peculiar situation; for the supposed insuperable firmness of the rest of the body, renders it a lever turning round the fulcrum A, and the individual cohesive power of each particle, such as D or E, acts by means of the arm, DA or E A. The precise energy of each particle will consequently be ascertained by multiplying the force individually exerted by it at the moment of fracture, by the arm of the lever which enables it to act.

Let us then suppose, that at the moment of fracture, every individual particle exerts an equal force f. The energy of D, will be D A $\times$ f, that of E will be E A $\times$ f, and that of the whole will be the sum of all these products. Let the depth D A, of the section, be called d, and let any undetermined part of it, as A E, be called x, then the space occupied by any particle will be $\dot{x}$. The cohesion of this space may be represented by f $\dot{x}$, and that of the whole by f d. The energy by which each element $\dot{x}$, of the line D A, or d, resists the fracture, will be f x $\dot{x}$, and the whole accumulated energies will be $f \times \int x\dot{x}$. This is well known to be $f \times \frac{1}{2} d^2$, or $fd \times \frac{1}{2} d$. It is the same thing, therefore, as if the cohesion f d, of the whole section, had been concentred together at the point G, which is in the middle of D A. A similar conclusion may be deduced from other principles. Suppose the beam, instead of projecting horizontally from a wall, to be suspended from a ceiling, in which it is firmly fixed. Let us next consider what effect the equal or accumulated cohesion of every part, has in preventing the lower part from separating from the upper, by opening round the joint A. The equal cohesion operates just in the same manner as equal gravity would do, but in a direction diametrically opposite. We know that the effect of this will be the same as if the whole weight were to be concentrated in the centre of gravity G, of the line D A, and that this point G will be in the middle of D A. Now the number of fibres being as the length d of the line, and the cohesion of each fibre being = f, the cohesion of the whole line is f $\times$ d or f d.

The accumulated energy, therefore, of the cohesion in the instant of fracture, is $fd \times \frac{1}{2} d$. Now this must be equal, or just inferior to the energy of the power employed to break it. Let the length A B, be called l; then P $\times$ l, is the corresponding energy of the power. This gives us $fd \times \frac{1}{2} d = p\,l$, for the equation of the equilibrium corresponding to the vertical section A B C D.

Let us suppose, however, that the fracture is not permitted at D A, but at another section m n, more remote from B. From the body being prismatic, all the vertical sections are equal; and, therefore, $fd \frac{1}{2} d$. is the same as before: but the energy of the power is nevertheless increased, it being in this instance, = P $\times$ B n, instead of P $\times$ B A. Hence, we may see, that when the prismatic body is not insuperably strong in all its parts, but only moderately, though equally strong throughout, it must break close at the wall, where the strain or energy of the power exerts itself with the greatest effect. We may see likewise, that a power which is just able to break it at the wall, is unable to break it any where else; and that the absolute cohesion f d, which withstands the power p in the section D A, will not withstand it in the section m n, though it resists more in the section o p.

This example affords a criterion for distinguishing between absolute and relative strength. The relative strength of a section has a reference to the strain actually exerted on that section; and this relative strength is properly measured by the power which is just able to balance, or overcome it, when applied at its proper place. Now since we had $fd \frac{1}{2} d = pl$, we deduce $p = \frac{f d d}{2 l}$ for the measure of the strength of the section D A, as it relates to the power applied at B. If the solid be a rectangular beam, whose breadth is b, it is evident that all its vertical sections will be equal, and that A G or $\frac{1}{2}$d, is precisely the same in all. Therefore the equation expressing the equilibrium existing between the momentum of the external force, and the accumulated momenta of cohesion, will be $p \cdot l = f d b \times \frac{1}{2} d$. The product d b, evidently expresses the area of the section of fracture, which we may call s; the equilibrium may be expressed thus: $pl = fs \frac{1}{2} d$, and $2l : d :: fs : p$.

Now f s, properly expresses the absolute cohesion of the section of fracture, and p, is a proper measure of its strength, as it relates to a power applied at B. We may, therefore, say, that *twice the length of a rectangular beam, is to the depth as the absolute cohesion is to the relative strength.*

Since the action of equable cohesion is similar to that of equal gravity, it follows, that whatever may be the figure of the section, the relative strength will

will be the same, as if the absolute cohesion of all the fibres, were exerted at the centre of gravity of the section. Let g represent the distance between the centre of gravity of the section and the axis of fracture, we shall have $p\,l = f\,g\,s$ and therefore $l : g :: f\,s : p$. This analogy in words is not unworthy of the readers recollection, and may be thus stated. *The length of a prismatic beam of any shape is to the height of the centre of gravity above the lower side, what the absolute cohesion is, to the strength that bears relation to this length.*"

Since the relative strength of a rectangular beam is $\frac{b\,d^2\,f}{2\,l}$, it follows, that the relative strengths of different beams, not only bear a proportion to the absolute cohesion of the particles, and to the breadth, but to the square of the depth directly, and to the length inversely; in prisms also whose sections are similar, the strengths are as the cubes of the diameters. This investigation has been conducted on the hypothesis of equal cohesion, a law not exactly conformable to the operations of nature. We know, for instance, when a force is applied transversely at B, that the beam bending downwards, becomes convex on the upper side; and that that side is, consequently, on the stretch. The particles at D are further removed from each other, than those at E, for which reason they exert greater cohesive forces. It is impossible to ascertain with certainty in what proportion each fibre is extended: but we will suppose for example, that their remoteness from each other is proportioned to the distance from A, a supposition which is by no means improbable. Now recollecting the general law, that the attractive forces exerted by dilated particles, are proportioned to the extent of their being dilated; let us suppose the beam to be so much bent, that the particles at D are compelled to exert their utmost energy, and that this fibre is just ready to break, or even actually breaks; it is plain in this instance, that an absolute fracture must ensue, since the force originally superior to the full cohesion of the particle at D, and a certain portion of the cohesion of all the rest, will become more than superior to the full cohesion of the particle next within D, and a smaller portion of the cohesion of the remainder.

Let F, represent as before, the full force of the exterior fibre D, exerted by it in the moment of breaking, when the force exerted at the same instant by the fibre E, will be shewn by this analogy, viz $d : x :: f : \frac{f\,x}{d}$ and the force really exerted by the fibre E, is $\frac{f\,x}{d}$.

The force exerted by a fibre whose thickness is $\dot{x}$. is therefore $\frac{f\,x\,\dot{x}}{d}$, but this force resists the strain through its being enabled to act by means of the lever E A, or x, its momentum therefore, is $\frac{f\,x^2\,\dot{x}}{d}$ and the aggregate momentum of all the fibres in the line A E, will be $f\int\frac{x^2\dot{x}}{d}$. This, when x, is taken equal to d, will express the momentum of the whole fibres in the line AD, which is $f\frac{d^3}{3\,d}$ or $f\,d \times \frac{1}{3}d$; now f d expresses the absolute cohesion of the whole line A D. The accumulated momentum, is consequently the same as if the absolute cohesion of the whole line were exerted at the distance of one third of A D, from A.

From the preceding, it follows, that the equation expressing the equilibrium of the strain and cohesion, is $p\,l = f\,d \times \frac{1}{3}\,d$, from whence the following analogy may be deduced, viz. "*As thrice the length is to the depth, so is the absolute cohesion to the relative strength.*"

This equation and proportion apply equally to rectangular beams, whose breadth may be b; since we shall then have $p\,l = f\,b\,d \times \frac{1}{3}d$.

We see, also, that the relative strength is not only proportioned to the absolute cohesion of the particles, and to the breadth, but to the square of the depth directly, and to the length inversely: for p is the measure of the force with which it is resisted, and $p = \frac{f\,b\,d\,\frac{1}{3}\,d}{l} = \frac{f\,b\,d^2}{3\,l}$. In this respect, therefore, the hypothesis, coincides with that of Galileo, except, that it assigns to every beam a smaller proportion of the absolute cohesion in the section of fracture, in the proportion of three to two. Galileo supposes that this section has a momentum equal to one half of its absolute strength, while in our hypothesis, it is only one third. In beams of a different form, the proportion may be different.

The consideration of the intricate problem of the elastic curve, which was first investigated by the celebrated James Bernouilli, is too deep and profound to be discussed in a publication like this, and we shall therefore briefly observe, in the first place, that the elastic curve cannot be a circle, but becomes gradually more incurvated, in proportion as it recedes from the point where the straining forces are applied. At this point it has no curvature, and if the bar were extended even beyond this point, still there would be no curvature. In conformity with this principle, when a beam is supported at the ends, and loaded in the middle, the curvature is greatest in the middle: but at the props, or beyond them, if the beam extend farther, there is no curvature. Therefore, when a beam

projecting 20 feet from a wall, is bent to a certain curvature at the wall, by a weight suspended at the end, and a beam of the same size projecting 20 feet, is bent to the very same curvature at the wall, by a greater weight, at 10 feet distance, the figure and the mechanical state of the beam in the vicinity of the wall, is different in these two cases, though the curvature close to the wall is the same in both. In the former case every part of the beam is incurvated; in the latter, all beyond the 10 feet, is without curvature. In the former case the curvature at the distance of five feet from the wall, is three fourths of the curvature at the wall; in the latter, the curvature at the same place, is only one half of that at the wall. This circumstance must tend to weaken the long beam, throughout the whole interval of five feet, because the greater curvature results from the greater extension of the fibres.

In the next place, we may remark, that a certain determinate curvature being suitable to every beam, it cannot be exceeded without breaking it; since two adjoining particles are thereby separated, and an end is put to their cohesion. A fibre, can be extended only to a certain degree of its length. The ultimate extension of the outer fibres, must bear a certain proportion to its length, and this proportion is similar in the point of depth, to the radius of ultimate curvature, which is, therefore, determinate. Consequently, a beam of uniform breadth and depth, is most incurvated where the strain is greatest, and will necessarily break in the most incurvated part. But by changing its form, so as to render the strength of its different sections in the ratio of the strain, it is evident that the curvature will be the same throughout, or that it may be made to vary according to any law.

Again, since the depth of the beam is thus proportioned to the radius of ultimate curvature, this curvature is inversely as the depth, and may be expressed by $\frac{1}{d}$.

We may observe also, that when a weight is suspended on the end of a prismatic beam, the curvature bears a very near proportion to the weight, and the length directly, and to the breadth and the cube of the depth inversely; for the strength is known to be $\frac{bd^2 f}{3 l}$, and let us suppose that this produces the ultimate curvature $\frac{1}{d}$, when, if the beam be loaded with a smaller weight w, and if the consequent curvature be represented by C, we shall have $\frac{bd^2 f}{3 l} : w :: \frac{1}{d} : C$; consequently, by incorporating the extreme and mean terms, and reducing the resulting equation, we shall deduce $C = \frac{3 l w.}{bd^3}$ This may be said also of a beam supported at its ends, and loaded between the props; by the same method, the curvature may be determined in its different parts, whether it arises from the load, from its weight, or from the united operation of both.

When a weight operates either at one end, or in the middle of a beam, the point where this weight is applied is necessarily bent down, and the distance through which it descends, has been termed the deflection; this may be considered as the versed sine of the arch into which the beam is bent, by the operation of the weight, and, therefore, is as the curvature when the length of the arch is given, (admitting the flexure to be moderate) or as the square of the length of the arch, when the curvature is given. The deflection consequently is as the curvature, and as the square of the length of the arch jointly; that is, as $l^2 \times \frac{3 l w}{b d^3 f}$ or as $\frac{3 l^3 w}{bd^3 f}$.

The deflection from the original shape, is as the bending weight and the cube of the length directly, and as the breadth and the cube of the depth inversely.

We may further observe, that in beams just ready to break, the curvature is proportioned to the inverse depth, and that the deflection bears a proportion to the square of the length divided by the depth; for the ultimate curvature at the breaking part is constantly the same whatever may be the length; and in this case the deflection is as the square of the length.

From this subject may be deduced various theorems, which afford excellent methods of enquiry, into the laws of corpuscular action. James Bernoulli, however, called this law, (which was originally laid down by the celebrated Dr. Hooke,) into question. Mariotte corrected it; but yet it does not properly explain the mechanism of transverse strains, as has been fully proved by various experiments.

Du Hamel made assiduous researches into the compressibility of bodies, which tended to confirm the observation of an eminent philosopher; "that the power of resisting a transverse strain is diminished by compressibility, and so much the more diminished as the stuff is more compressible."

Du Hamel, took 16 bars of willow, 2 feet long, and ½ an inch square, and after supporting them by props under the ends, he subjected them to the operation of weights suspended at the middle. Four of them were broken by weights of 40, 41, 47 and 52 pounds; the mean of which is 45lbs. He then cut through one third of four of them, on the upper side, and filled up each cut, with a thin piece of harder wood stuck in tolerably tight. These several

veral pieces were then broken by weights of 48, 54, 50 and 52 pounds; the mean of which is 51lbs. Four others were then cut through one half, and broken by 47, 49, 50 and 56lbs; the mean of which is 48lbs. The other four were cut through two-thirds, and their mean strength was 42lbs.

At another time Du Hamel took six battens of willow 36 inches long, and 1¼ square; after suitable experiments, he found that they were broken by 525 pounds at a medium.

Six bars were next cut through one-third, and each cut was filled with a wedge of hard wood stuck in with a little force, these were broken by 551 pounds on the average.

Six other bars were broken by 542lbs on the medium, when cut half through, and the cuts were filled up in a similar manner.

Six other bars were cut three-fourths through, and broken by the pressure of 530 pounds on a medium.

A batten was cut three-fourths through, and loaded until nearly broken, it was then unloaded, and a thicker wedge was introduced tightly into the cut, so as to straighten the batten, by filling up the space left by the compression of the wood, when the batten was broken by 577 pounds.

From these experiments we may, perceive that more than two-thirds of the thickness, we may, perhaps, with safety say nearly three-fourths contributed nothing to the strength. From hence, we see also, that the compressibility, of bodies has a very great influence on their power of withstanding a transverse strain. We may observe, likewise, that in this most favourable supposition of equal dilatations and compressions, the strength is reduced to one half of the value of what it would have been, had the body been incompressible; and, although this may not seem obvious, at first sight, yet it will, readily, appear when the case is considered. In the instant of fracture, a smaller portion of the section exerts its actual cohesive forces, while a part of it serves only as a fulcrum to the lever, by whose means the strain on the section is produced; and we may further perceive, that this diminution of strength does not depend so much on the sensible compressibility, as on the proportion it bears to the power of being dilated by equal forces. The foregoing experiments on battens of willow, moreover shew, that its compressibility is very nearly equal to its dilatability.

Experiment alone can render us efficient aid, in investigating the degree of proportion that exists between the compressibility, and dilatability of bodies; and the nature of the strain we have just been considering, is peculiarly adapted to guide us in the research. Thus, if a piece of wood, an inch square, requires 12000 pounds to tear it asunder by a direct pull, while 200 pounds will break it transversely, by acting 10 inches from the centre of fracture, we may conclude that the attractive and repulsive forces are equal. By the ideas we entertain concerning the particular constitution of such fibrous bodies as timber, we are led to conceive that the sensible compression, which arises from the bending up of the compressed fibres, are much greater than the real corpuscular extensions. This circumstance, however, will be better comprehended, after we have considered what must happen during the fracture. An undulated fibre can be drawn straight only, when the corpuscular extension begins; but it may be bent up by compression to any degree, the corpuscular compression, being but little affected all the time. This fact is of an important nature. Though the forces of corpuscular repulsion, may be deemed almost insuperable by any compression we can employ, a sensible compression, nevertheless may be produced, by forces not enormous, but sufficient to cripple the beam.

The proportional strengths of different pieces, follow the same ratio; for, although the relative strength of a prismatic solid have been considered as extremely different in the foregoing hypotheses, yet the proportional strengths of different pieces follow the same ratio, that is, the direct ratio of the breadth, the direct ratio of the square of the depth, and the inverse ratio of the length. We derive, also, from this important fact, the useful information, that the strength of a piece depends most on those dimensions which lie in the direction of the strain; or, to use other words, it depends more on its depth than on its thickness. The strength of a bar of timber, two inches in depth, and one in thickness, is four times more than that of a bar of an inch square, while, at the same time, it is twice as strong as a bar two inches broad, and an inch deep. The manner in which cohesion opposes itself to a strain, may be farther exhibited and applied, by supposing a triangular beam to be fixed firmly by one end in a wall, with its other end unsupported, and to be acted on by a certain weight; in which position it will bear three times more weight, when one of its sides is uppermost, as it would if it were undermost. Thus, for example, the triangular beam, delineated at *Figure* 4, is three times as strong, when the side A B is uppermost, and the edge D C is undermost, as it would have been, if the edge D C were uppermost, and the side A B undermost.

Hence, also, we may find, that the strongest rectangular beam, which can be cut out of a given cylindrical tree, is not that, which contains the greatest quantity of timber, but that the product of whose breadth, by the square of its depth, is a maximum, or the greatest possible. The following solution will shew, that the squares of the breadth and depth with the square of the diameter, are, respectively, as the numbers 1, 2 and 3.

In *Figure* 5, let A B, the diameter of the cylindrical tree, be designated by D, let the depth A C, of

of the beam, be shewn by d, and the breadth B C by x, then, when B C, is horizontal, the lateral strength will be truly represented by $d^2 x$, which, agreeably to the conditions of the problem, must be a maximum; but we know, from the nature of the figure, that $A C^2 = A B^2 - B C^2$, or $d^2 = D^2 - x^2$, hence, then $(D^2 - x^2) x = D^2 x - x^3$ expresses the maximum: this put in fluxions, is $D^2 \dot{x} - 3 x^2 \dot{x} = o$, or $D^2 \dot{x} = 3 x^2 \dot{x}$, whence $3 x^2 = D^2$ and therefore $d^2 = D^2 - x^2 = 3 x^2 - x^2 = 2 x^2$, consequently $x^2 : d^2 : D^2 :: 1 : 2 : 3$ as before observed.

From this solution, we deduce the following very easy mode of construction, which every practical carpenter may apply with the greatest facility. Divide the diameter A B, into three equal parts, at the points E F; erect the perpendiculars E D, F C, and join the points C D, to the extremities of the diameter, when A B C D, will be a section of the rectangular beam required. For, in consequence of A E, A D, and A B, being in continued proportion, we have $A E : A B :: A D^2 : A B^2$; and similarly $A F : A B :: A C^2 : A B^2$. Hence, $A E : A F : A B :: A D^2 : A C^2 : A B^2 :: 1 : 2 : 3$.

The ratio of x to d, is very nearly that of 5 to 7, or still more nearly, that of 12 to 17.

The strength of A B C D, is to that of A a B b, as 10000 to 9186, and the weight and expence, are as 10000 to 10607; so that A B C D, is preferable to A a B b, in the proportion of 10607, to 9186, or nearly as 115 to 100.

A square beam from the same cylinder, would have its side $= D\sqrt{\frac{1}{2}} = \frac{1}{2} D\sqrt{2}$. Its solidity would be to that of the strongest beam, as $\frac{1}{2} D^2$ to $\frac{1}{3} D^2 \sqrt{2}$, or as $\frac{1}{2}$ to $\frac{1}{3}\sqrt{2}$, or as 5 to ·4714; while its strength would be to that of the strongest beam as $(D\sqrt{\frac{1}{2}})^3$ to $D\sqrt{\frac{1}{3}} \times \frac{2}{3} D^2$, or as $\frac{1}{4}\sqrt{2}$ to $\frac{2}{9}\sqrt{3}$, or as 3560 to 3849.

We may further remark, in conformity with the observation just now made, that either of these beams will be enabled to exert its greatest lateral strength, when the diagonal part of one of its ends is placed in a vertical position; since, from the area of the section being the same in both positions, the strength is known to vary in the same manner as the distance of the centre of gravity varies from the base of fracture; but when one of the sides is vertical as in *Figure* 6, the distance of the centre of gravity of the end will be A I or I D, that is, equal to half the side; whereas in the case where the diagonal is vertical, as in *Figure* 7, that distance will be C E or E D, that is, half the diagonal.

By the application of the same principle, we may discover, that a hollow tube is stronger than a solid rod containing the same quantity of matter.

Let the diagram, delineated at *Figure* 10, represent the section of a cylindrical tube, of which A F and B E are the exterior and interior diameters, and C the centre; draw B D perpendicular to B C, and join D C; then because $B D^2 = C D^2 - C B^2$, B D is the measure of the radius of a circle, which contains the same quantity of matter as the ring. If the strength be estimated by the first hypothesis, the strength of the tube will be to that of the solid cylinder, whose radius is B D, as $A C \times B D^2$ to $B D \times B D^2$, or as A C to B D by division of ratio.

Otherwise, let A B E, H I K, as in *Figures* 9 and 10, represent the ends of two cylinders of equal length, and containing equal quantities of matter, the former of which, however, is supposed to form the section of a tube, composed of cylinders with a common axis. We know that the lateral strengths are conjointly, as the areas and the distances of the centres of gravity of the sections, from A or from B, accordingly as the fractures may terminate at the one or the other point; but the areas of the annulus in *Figure* 9, and of the circle in *Fig.* 10, are equal, and the centres of gravity of both are at their centres of magnitude, for which reason, since the radii vary in the same manner as the diameters, the strengths, in this case, also vary in a similar ratio.

When the area of a circular section is given, its diameter is greater if the section form an annulus, than when it is a circle without any cavity: and since the power, with which the parts of the cylinder resist the operation of extraneous force, is greater in the same proportion, it follows, according to the theory thus stated, that the strength may be increased, indefinitely, without increasing the quantity of matter.

The absurdity of this conclusion becomes manifest, when we enquire, will not the tube be rendered flaccid after the diameter exceeds a certain limit, and therefore bend under the smallest additional weight? The fact is simply this, the foregoing theory is founded on the supposition, that the figure of the section will constantly remain circular; but this supposition does not apply, except under those circumstances, where the pressure or stroke upon the tube, will not cause its section to degenerate from its circular shape to an elliptical, or any other figure.

By way of illustration, let a hole be bored, lengthwise, through a cylinder of half its diameter, then the strength in this instance, is diminished $\frac{1}{8}$th, while the quantity of matter is diminished $\frac{1}{4}$th.

Galileo, from a consideration of this subject justly concludes, that nature, in a thousand operations, greatly augments the strength of substances without increasing their weight; as is manifested in the bones of animals, and the feathers of birds, as well as in most tubes, or hollow trunks, which though light, greatly resist any effort made to bend or break them. "Thus (says he) if a wheat straw, which supports an ear that is heavier than the whole stalk

were made of the same quantity of matter but solid, it would bend or break with far greater ease than it now does And with the same reason art has observed, and experience confirmed, that an hollow cane, or tube of wood or metal, is much stronger and more firm, than if, while it continued of the same weight and length, it were solid, as it would then, of consequence, be not so thick; and therefore art has contrived a method to make lances hollow within, when they are required to be both light and strong." In this instance, as in many others, imitating the wisdom of nature.

In all such instances, however, there is an obvious distinction between the works of nature and those of art; "in the former" (as M. Girard remarks, when treating of the same subject,) "the cause and effect essentially agree; the one cannot undergo any modification, without the others experiencing a correspondent change; or, to speak more precisely, a new effect always results from a new cause.—In the productions of human industry, on the contrary, there is no necessary proportion between the effect and cause; if, for example, a determinate weight is to be raised, it is indifferent whether we use the thread which has precisely the adequate force, or the cable which has a superabundent one; while, if the same weight had rested naturally suspended, it would have done so by means of fibres peculiarly appropriated, in their organization, to the object, and whose disposition would have presented the most advantageous form. Perfection resides in a single point, at which nature arrives without effort; while man is obliged, by repeated trials, to pass over an immense space which separates him from it."

Our best engineers have wisely begun to imitate nature, by making many parts of their machinery hollow, such as t e axles of cast iron &c.

In the supposition of homogeneous texture, the fracture happens as soon as the particles on the upper sides D A, *Figure* 11, are separated beyond their utmost limit of cohesion; this is a determined quantity, and the piece bends until a similar degree of extension is produced in the outermost fibre. It follows, as a very necessary consequence, that the smaller we suppose the distance to be, between the upper part of the beam and the centre of fracture C, the greater will be the curvature acquired by the beam before it breaks. We may perceive, therefore, that an increase of depth not only renders a beam stronger, but stiffer; however, if the parallel fibres are supposed to slide on each other, the degree of strength and stiffness will be diminished. Instead of one beam, let us, by way of illustration, suppose A B C D, and C D E F, to represent two equal beams, which do not co-here, but whose aggregate magnitude shall be equal to the former beam. In this instance it is plain that each of them will bend, and that the extension of the fibres C D of the under beam will not, by any means, prevent the compression of the adjoining fibres C D of the upper beam. The two beams therefore, instead of being four times as strong as a single beam, will only be of twice the strength; and they will moreover bend as much as a single beam would be affected, by half the load. This, undoubtedly, could be prevented, if it were possible to unite the two beams firmly in the joint C D, so as to prevent one from sliding on the other. In smaller works, however, it may be effected by gluing them together with a cement, proportioned, in point of strength, to the natural lateral cohesion of the fibres.

But as this desideratum cannot be obtained in large works, the sliding may be prevented by joggling the beams together; various methods for which have been already exhibited in our third plate of Carpentry.

It is, nevertheless, possible to combine strength with pliability, by forming a beam of several thin planks laid on each other, till they form the required depth, and afterwards leaving them at full liberty to slide on each other. Coach springs are formed after this mode, as is shewn in *Figure* 12. Neither joggles nor bolts of any kind should be introduced among the planks; but they must be kept together solely by straps contrived so as to surround them, or by something else of a similar nature.

From long experience, practical men have been enabled to introduce into their constructions many principles which sound theory does not decline to sanction. This, for instance, when a mortise is required to be cut out of a piece exposed to a cross strain, it should be taken from that side which becomes concave by the strain, as in *Figure* 13, but by no means as in *Figure* 14.

Farther, when a piece is to be strengthened by the addition of another, the piece to be added, should be fixed to the side which grows convex by the strain, as in *Figures* 15 and 16.

We shall next consider the analogy that exists between the strain on a beam projecting from a wall, and loaded at the extremity, and a beam supported at both ends, and loaded at some intermediate part.

Let A C B, *Figure* 16, represent the beam supported by the props A and B, and loaded at its middle point C, with a weight W; when it is evident that the beam will receive the same support, and become subject to the same strain, as if, instead of the supports A and B, the ropes A a E, B b F, which pass over the pullies a, b, were to be substituted, and have the proper weights E, F, fastened to them. These weights are equal to the support afforded by the points of support, while their sum is equivalent to the weight W; and on whatever point W, may be hung, the weights E and F, are to the weight W, in the proportion of D B, and D A, to A B. From hence, it appears, that the strain on the section C D, arises immediately from the upward action of the ropes A a, and B b, or from the pres-

 sure

sure exerted upwards by the points of support A and B, and the office of the weight W, is obliging the beam to oppose this strain. The beam has a tendency to break in the section C D, because the ropes pull it upwards at E and G, while the weight W, confines it down at C. It inclines to open at D, and C, becomes the centre of fracture. The strain, therefore, is the same as if the half A D, were fixed in the wall, and a weight equal to the one-fourth of W, were applied at G.

From these circumstances we may conclude, that a beam supported, but not fixed at both ends, and loaded in the middle, will bear four times as much weight as it would be capable of supporting at one extremity, when the other is fast in a wall.

The strain occasioned at any point I, by a weight W, suspended at any other point D, is $W \times B\,I \times \frac{D\,A}{A\,B}$. For it is known, that AB : AD :: W : the pressure occasioned at B. This would be balanced by some weight F, acting over the pulley b, which tends to break the beam at I, by acting on the lever I B. The pressure at B, is $W \times \frac{D\,A}{A\,B}$, and therefore the strain at I, is $W \times \frac{D\,A}{A\,B} \times I\,B$.

In a similar manner, when the strain occasioned at the point D, by the weight W, is $W \times \frac{A\,D}{A\,B} \times D\,B$, which is equal to $\frac{1}{4}$ W, when D forms the middle point.

Hence then, we deduce, that the general strain on a beam arising from a particular weight, bears a proportion to the rectangle of the parts composing the beam, and is greatest when the load is laid on the middle of the beam, which latter circumstance, is confirmed by daily experience.

Farther the strain at I, by a load at D, is equal to the strain at D, by the same load at I, and the strain at I, from a load at D, is to the strain by the same load at I, as D A, is to I A. If we now suppose the beam to be firmly framed at the two ends L M, into the upright posts L N, M O, placed beyond the former points of support A B, then it will carry twice as much as when its ends were free; for admitting the beam to be sawn through at C D, the weight W, suspended there, will be but just sufficient to break it at A and B, while, by restoring the connection of the fibres composing the section C D, it will require another weight W, to break it there at the same time.

It should be observed, therefore, that when any piece of timber is firmly connected at three fixed points B, A, L, it will bear a greater load between any two of them, than if it had no connection with the remote point; and if it be firmly fastened at the four points L, A, B, M, it will be twice as strong in the middle part, as it would be when deprived of the two remote connections.

It may be thought, perhaps, from the preceding observation, that the joist of a floor, or a girder, will derive an increase of strength, from being firmly built in the wall. However plausible this idea may appear, the fact is, that it derives but little additional strength, for the hold thus afforded to it, is too circumscribed in its effect, to render much essential service, and farther, it tends greatly to shatter and crack the wall, when the beam is pressed by any considerable load, since it forces up the wall with all the energy of a long lever. For this reason, those builders who are most eminent for their practical knowledge, never allow the ends of their joists or girders, to be bound tight in walls; but when the joists of adjoining rooms lie in the same direction, they justly consider it a great advantage gained, to have them in one piece, because, in that form, they are twice as strong as when composed of two lengths.

Having taken a view of the circumstances which affect the strength of any section of a solid body, when strained transversely, it may next be proper to take notice of some of the chief modifications of the strain itself, that occur most frequently in our constructions.

This strain depends on the operation of external force, and also on the lever on which it acts; for, since the strain may be produced in any section, by means of the cohesion of those parts which intervene between the section, (under consideration), and the point of application of the external force, the body must have sufficient energy in all those intervening parts, to excite the strain in the remote section, and in every part it must be able to resist the strain excited in that part. The body, therefore, ought to be equally strong, and it is useless to have any one part stronger; because the piece will nevertheless break when it is not stronger throughout, and it is useless to make it stronger with regard to its strain, for it will, nevertheless, equally fail in the part that is too weak.

If the strain arises from a weight suspended at one extremity, while the other end is supposed to be fixed firmly in a wall; or if each transverse section of the beam be rectangular; there are several ways of forming the beam so as to render it equally strong throughout.

Let *Figure* 17, represent the intended beam which is fixed to the vertical wall B E, and has a weight W, suspended at A, its extremity. It is obvious that the effort made by the weight W, upon any point D, of the beam, will, by the common properties of the lever, be as the rectangle W × A D, or as A D, since the weight W is constant and invariable. The strength also at any point D, is as the breadth into the square of the depth at that place, or as the breadth C D, the depth being constant. Consequently

Consequently, when the beam is equally strong throughout, the strength and stress are in an invariable ratio, and we shall have CD, constantly as A C; and therefore A C D must be a rectilineal triangle, and the form of the beam a wedge.

Again, if we suppose the beam to be of uniform breadth, its length must be proportional every where to the square of its depth, if it be fixed horizontally by one end in a wall, and a weight operate on the extremity of the other.

The following solution, will exhibit this most interesting particular, in a clear point of view.

On referring to *Figure* 18, we observe that the stress is as the length A D in the same manner as in the preceding, and that the strength is as the breadth into the square of the depth, or because the breadth is constant by the conditions of the problem, the strength is as C D^2. But the stress and strain must remain in a constant ratio: wherefore A D must vary as C D^2; this law, it may be observed, acts invariably throughout the figure, and is the well known property of a parabola whose vertex is A.

The following circumstance, which is worthy of notice, may be immediately deduced from the preceding solution, by way of corollary. Since the parabola is $\frac{2}{3}$ of the parallelogram which circumscribes it, it follows, that parabolic beams require $\frac{1}{3}$ less matter than prismatic ones; this circumstance may be beneficially attended to, in cases where iron is used.—

It is also deserving of remark.

That the beams of balances intended to support very great weights, may be constructed of a parabolic shape, which will have the effect of saving materials without any diminution of useful strength.

To pursue this subject still farther, let us suppose that another beam has one end fixed to a wall, and is diminished gradually towards the other end, where a weight, if suspended, so that all its vertical sections, such as circles, squares, similar polygons &c. may be similar; in this case, in order to render the beam equally strong throughout, the bounding curve must be in the form of a cubic parabola.

If we refer to *Figure* 19, we find that the stress or effort of the weight which operates upon any point F, will be as A F; and, since the sections are all similar, the strengths will vary as the cubes of the depths. Hence, in this case, AF is as D C^3, which is a well known property of the cubic parabola.

All these modes of forming beams render them equally strong in all their parts, and they are all supposed to have the same section at the front of the wall, or at the fulcrum. They are not, however, equally stiff. The beam represented in *Fig.* 17, will bend the least, upon the whole, while that in *Figure* 19, will bend the most, but the curvatures at the fulcrum will be precisely the same in all the beams.

The same principles, and the same construction, apply to beams when supported at their ends, and loaded at some intermediate part.

We have hitherto confined our remarks to the supposition that the external straining force acts only in one point of the beam. But, it is proper to observe, that this may be uniformly distributed all over the beam. To form a beam equally strong under such circumstances, the shape must be contrived very differently from the former.

If we suppose a beam to project from a wall, and to be of equal breadth thoughout, with its sides forming vertical planes parallel to each other, and to the length the vertical section, in the direction of its length, must be a triangle instead of a common parabola; since the weight uniformly distributed over the part, from lying beyond any section, is as the length beyond that section, and since also this way it may be considered as collected at its centre of gravity, which of course is the middle of that length, the lever by which this load strains the section of course bears a proportion to the same length. The strain on the section is as the square of that length, and the section must have strength in the same proportion. From its strengths being as the breadth, and the square of the depth, and from the breadths being constant, the square of the depth of any section must be as the square of its distance from the end, and the depth must be as that distance; and, therefore, the longitudinal vertical section must form a triangle.

But if all the transverse sections are supposed to be squares, circles, or any other similar figures, the strength of every section must be proportioned to the square of the lengths beyond that section, or the square of those sections, distance from the end; in which case, the sides of the beam must be a semicubical parabola.

If the upper and under surfaces are supposed to be horizontal planes, it is evident that the breadth must be proportioned to the square of the distance from the end; and the horizontal sections may be formed by arches of the common parabola, having the length for their tangents at the vertex.

We shall next direct our attention to the proper form of a beam intended to be fixed at one end, and uniformly loaded throughout its whole length, so as it may be rendered equally strong in all its parts. The vertical sides of this beam we will suppose to be parallel planes, in which case the beam will be of equal thickness throughout, and, therefore, the strength at any part D C, will be as C D^2, or as C c^2, accordingly as A DB, or A c B, represent the bottom of the beam (*Fig.* 20). Now the stress at the point D, is as the rectangle A D,$\times$D B; for which reason C D^2 or C c^2 must vary as A D,$\times$D B, in order to ensure equal strength throughout. This, it is well known, is the fundamental principle of the ellipse, the vertices of which are A and B.

If the transverse sections be similar, we must make C D^3, as A C$\times$C B.

If the upper and under surfaces are parallel, the breadth must be as A C$\times$C B.

If,

If, however, the beam is necessarily loaded at some given point C, and we would have it equally able, in all its parts, to resist the strain arising from the weight at C, we must proportion the strength of every transverse section between C, and either end, to its distance from that end; for which reason, if the sides are parallel vertical planes, we must make $C D^2 : E F^2 :: A C : A E$.

If the sections are similar, then $C D^3 : E F^3 :: A C : A E$.

If the upper and under surfaces are parallel, then the breadth at C : breadth at E :: A C : A E.

The same principles lead to the conclusion, that all circular plates, whether large or small, provided they be of the same matter and thickness, and supported all round on the edges, will bear equal weights. This conclusion applies also to square plates, or any other ones of a similar figure.

The weight, moreover, which a square plate will bear, is to that able to be borne by a bar of the same matter and thickness, as twice the length of the bar to its breadth.

There is yet another modification of the strain which tends to break a body transversely, and which occurs very frequently; this is the strain arising from its own weight, and it requires some consideration in many instances.

When a beam projects from a wall, every section is strained, by the weight of all that projects beyond it. This weight may be considered as operating at its centre of gravity. Hence, the strain on any section is in the joint ratio of the weight of the part which projects beyond it, and the distance of its centre of gravity from the section.

The determination of this strain, as well as of the strength required to withstand it, is more difficult of attainment than the former, because the mode in which the piece may be formed to meet or adjust the strain, has a considerable influence on the strain itself. It may be admitted, perhaps, as a general principle, that the strength of cohesion in every section, must be as the product of the weight beyond it multiplied by the distance of its centre of gravity. The result of the application of this general principle is, that the depth must be as the square of the distance from the extremity, and the curve will then form a parabola touching the horizontal axis of the figure.

We may perceive, therefore, that a conoid formed by the rotation of this figure round its axis, will have sufficient strength in every section, to bear its own weight.

A projecting beam becomes less able to bear its own weight, in proportion to the extent of its farther projection; and whatever may be the strength of the section, the length, nevertheless, may be such as to render it liable to break by its own weight. For instance, if we suppose two beams to be composed of similar matter, with their diameters and lengths in equal proportion, but that the shorter beam can only just bear its own weight, then the longer beam will not be able to do the same; since the strengths of the sections, are as the cubes of the diameter, while the strains are as the fourth powers of the same.

From these considerations, we may take it for granted, that in all cases where a strain is produced by the weight of the parts composing a machine, or structure of any kind, the smaller bodies are more capable of withstanding it than the greater. Indeed a limit seems to be set by the hand of nature to the size of machines, of whatever materials they may be constructed; for, even when the weight of the parts composing a machine is not taken into the account, we cannot enlarge it so as to produce a similar proportion in all its parts. A limit is evidently set by nature to the size of animals and plants, when formed of the same matter. The attraction of cohesion in an herb could not support it, if it were increased to the size of a tree, neither could an oak support itself, if it were forty or fifty times larger than it is, nor could an animal resembling in its make, a long legged spider be augmented to the size of a man.

The celebrated Dr. Gregory, has some invaluable observations on this subject in his "*Treatise on Mechanics*."

He says "From the preceding deductions it follows, that greater beams and bars must be in greater danger of breaking, than the less similar ones; and that, though a less beam may be firm and secure, yet a greater similar one may be made so long, as necessarily to break by its own weight. Hence, Galileo justly concludes that what appears very firm, and succeeds well in models, may be very weak and unstable, or even fall to pieces by its weight, when it comes to be executed in large dimensions, according to the model. From the same principles he argues, that there are necessarily limits in the works of nature and art, which they cannot surpass in magnitude; that immensely great ships, palaces, temples, &c. cannot be erected, their yards, beams, bolts, &c. falling asunder by reason of their weight. Were trees of a very enormous magnitude, their branches would, in like manner, fall off. Large animals have not strength in proportion to their size; and if there were any land animals much larger than those we know, they could hardly move, and would be perpetually subjected to most dangerous accidents. As to the animals of the sea, indeed, the case is different, as the gravity of the water sustains those animals in great measure, and in fact these are known to be sometimes vastly larger than the greatest land animals; it is, says Galileo, impossible for nature to give bones for men, horses, or other animals, so formed, as to subsist, and proportionally to perform their offices, when such animals should be enlarged to immense heights, unless she uses matter much firmer, and more resisting than she commonly does; or

or should make bones of a thickness out of all proportion; whence the figure and appearance of the animal must be monstrous. This he supposes the Italian poet hinted at, when he said."

"Whatever height we to the giant give,
He cannot without equal thickness live."

"And this sentiment being suggested to us by perpetual experience, we naturally join the idea of greater strength and force with the grosser proportions, and that of agility with the more delicate ones. The same admirable philosopher likewise remarks, in connection with this subject, that a greater column is in much more danger of being broken by a fall, than a similar small one; that a man is in greater danger from accidents than a child; that an insect can sustain a weight many times greater than itself; whereas a much larger animal, as a horse, could scarcely carry another horse of his own size. The ingenious student may easily extend these practical remarks, to any cases which may come before him."

The compression of materials is another object, that demands our most serious consideration. In adverting to the operation of strains of this kind, it is absolutely impossible to conceive how a piece of timber, that is perfectly straight, can be bent, crippled, or broken, by the application of any force whatever at the extremes. But, if a very small force be supposed to act in the middle, in a direction at right angles with the length, it will be sufficient to give it some certain small degree of curvature; and if a powerful force be likewise supposed to act at the ends, at the same time, so as both the greater and the lesser force shall press on the timber in the direction of its length, these forces will conjoin together in producing the effect of a fracture.

The first author who considered the compression of columns with any degree of proper attention, was the ingenious and learned Euler. This eminent philosopher in the *Berlin Memoirs* for 1757, published his "*Theory on the strength of columns.*" The general proposition endeavoured to be established by this theory is, that the strength of prismatic columns is in the direct quadruplicate ratio of their diameters, and the inverse ratio of their lengths. He prosecuted this subject in the *Petersburgh commentaries* for 1778, where he confirms his former theory. Muschenbroek has compared Eulers theory with the results of his own experiments, but the comparison has produced nothing that is satisfactory; since the variation existing between the experiments and the theory, is so enormous, as to offer no argument for the correctness of the latter. Still, however, the experiments do not contradict it, though they are so very anomalous, as to lead to no conclusion or general rule whatever.

In consequence of our intimation, that the theory of Euler may be deemed erroneous, it may be asked, what is the true proportion in the strength of pillars or columns? We have not the means of giving a satisfactory answer, which could proceed only from the result of a previous experience of the proportion existing between the extensions, and compressions, produced by the operation of equal forces; that is, from knowing accurately the absolute compressions produced by a given force, as well as the degree of that derangement of parts, which is termed crippling. Unfortunately very little is known on these points, and consequently a wide field of experimental enquiry lies before us. It may be considered fortunate, however, that the force required to cripple a beam is prodigious, and that a very small lateral support only, is sufficient to prevent that bending, which places the beam in imminent danger of destruction. A judicious mechanic will always employ transverse bridles, (as they are termed), in order to stay the middle of long beams intended to perform the office of pillars, truss beams, struts, &c. and exposed from the nature of their peculiar position, to immense pressures in the direction of their lengths, but such stays should be arranged in a judicious, as well as economical manner.

As experiments on the transverse strength of bodies are easily made, they have been accordingly very numerous, particularly on timber; but amid this great variety of experiments, few have afforded that practical information which is so desirable. The generality of them have been made on very small scantlings, (in which the unavoidable natural inequalities, bear too great a proportion to the strength of the whole piece,) for which reason, the results of the experiments of different persons have varied considerably, and even between those made by the same person, great irregularities have existed.

Belidor, has presented us in his "*Science des Ingénieurs,*" with the most complete series of experiments that has come under our notice.—His results appear in the following table; and the pieces on which he made his several trials, were sound, even grained oak.

The column B comprises the breadth of the pieces in inches; the column D contains their depths; the column L includes their lengths; P demonstrates the weight (in pounds) which broke them, when hung on their middles; and the column M points out the mediums.

In order to obtain the respective strengths of pieces of different dimensions, with more certainty, three pieces of each dimension were tried, under the expectation that the medium would be better shewn, by repeated trials, than by a single experiment.

	B	D	L	P	M
Experiments 1st, ends loose	1	1	18	400 415 405	406
Experiments 2d, ends firmly fixed	1	1	18	600 600 624	608
Experiments 3d, ends loose	2	1	18	810 795 812	805
Experiments 4th ends loose	1	2	18	1570 1580 1590	1580
Experiments 5th, ends loose	1	1	36	185 195 180	187
Experiments 6th, ends fixed	1	1	36	285 280 285	283
Experiments 7th, ends loose	2	2	36	1550 1620 1585	1585
Experiments 8th, ends loose	$1\frac{2}{3}$	$2\frac{1}{3}$	36	1665 1675 1640	1660

By comparing the first experiment with the third, the strength appears proportional to the breadth, while the length and depth of each piece are the same.

By comparing the first and fourth experiments together, the strength appears as the square of the depth nearly, while the breadth and length are all the same.

By comparing the first and fifth experiments together, the strength appears to be nearly as the lengths, inversely, while the breadth and depth of each piece are the same.

By comparing the fifth and seventh experiments together, the strengths appear to bear a near proportion to the breadth, multiplied by the square of the depth, while the length is the same in both.

By comparing the first and seventh experiments together, the strengths are shewn to be as the square of the depth, multiplied by the breadth, and divided by the length. Experiments the first and second shew the increase of strength acquired by fastening the ends, to be in the proportion of 2 to 3. Experiments the fifth and sixth demonstrate the same thing.

This, irregularity in the result of experiments may be ascribed to the fibrous or plated texture of timber; which, as is well known, consists of annual additions, whose cohesion with each other is much weaker than that of their own fibres. Let the diagram denoted by *Figure* 21, represent an horizontal section of a tree, and the parallelograms A B C D, a b c d, exhibit the section of two battens cut out of the tree, for the purpose of making experiments. In these parallelograms we intend A D, a d to point out the measure of their depths, and D C, d c to represent that of their breadths. It is evident that the fibres composing the section A B C D, may be considered as an assemblage of planks set edgeways, while those which form the section a b c d, may be considered as laid flatways; but we know both from theory, and experience, that the former is stronger than the latter, and the reason of this may be easily explained. A series of planks, set edgeways, will form a stronger beam than planks laid on each other like the plates of a coach spring. Buffon made some experiments on oak, in order to ascertain the ratio of strength in these parallelograms; after many trials, he found that the strength of A B C D, was to a b c d, nearly as 8 to 7. Buffon, however, (like other experimentalists) did not take care to have the plates of the battens disposed in a similar manner with respect to the strain; still had this precaution been taken, his experiments would not have furnished sure grounds of computation for constructing works in which large timbers are required; and, it should be observed, that, as large timbers occupy a great deal if not the whole of the section of a tree, their strength is proportionably less than that of a small lath or batten.

Here, again, we feel ourselves embarassed and at a loss for the want of an extensive series of suitable experiments on large timbers. To unite the principles of accuate theory with the results of judicious and extensive experiments, would, ultimately, tend to promote the arts and manufactures of this country. Besides, as an excellent writer most justly observes, "a forbidding distance, and awkward jealousy, seem to subsist between the theorists, and the practical men engaged in the cultivation of mechanics in this country." And, therefore, it is a most laudable task to endeavour "to shorten this distance, and to eradicate this jealousy." For, while we prize the deductions of sound theory, and rely firmly upon their results, we should nevertheless recollect, that, "as all general principles imply the exercise of abstraction, it would be highly injudicious not to regard them in their practical applications as approximations, the defects of which must be supplied, as indeed the principles themselves are deduced, from experience." Theoretical as well as practical men would not only greatly promote their mutual interests, by blending and uniting their efforts, but render an essential service to mechanical science. There are few persons who do not enjoy sufficient occasional leisure and opportunity, for making *some* experiments on the strengths of bodies; the results of their several efforts, would tend to elucidate and advance the subject. But since these

these experiments, when made on an extensive scale, are both laborious, and beyond the means of most individuals who may be inclined to enquire into the subject, it is singular in an empire like this, which is certainly the most eminent in the world for its extensive mechanical structures, that a judicious series of suitable experiments has not been made, on a liberal and extensive scale, with a view to the knowledge of those laws which regulate the strengths of different materials, accordingly as different strains may operate.

Amid this deplorable want of information in our own country, we must have recourse to the Continent, and solicit the aid of those philosophers, who have investigated the subject with the most attention. Buffon and Du Hamel were supplied by the old government of France, with ample funds and extensive apparatus for carrying on the necessary experiments. A description of these is to be found in the memoirs of the French academy for 1740, 1741, 1742, and 1768; as well as in Du Hamel's ingenious performances *sur l' Exploitation des arbres, et sur la Conservation et le Transport de Bois*.

Our readers may not be dissatisfied with an abstract of M. Buffons experiments.

This ingenious philosopher prosecuted, during two years, a variety of experiments on small battens of oak. He found, however, from these experiments, that the variation in a single layer, or in part of a layer, either more or less, or even a different disposition of them, had so much influence that he was under the necessity of abandoning the method, and proceeding to operate on the largest beams that he could possibly break. The annexed table shews a series of experiments on bars of sound oak, four inches square, and free from knots.

1	2	3	4	5
7	60	5350	3·5	29
	56	5275	4·5	22
8	68	4600	3·75	15
	63	4500	4·7	13
9	77	4100	4·85	14
	71	3950	5·5	12
10	84	3625	5·83	15
	82	3600	6·5	15
12	100	3050	7	
	98	2925	8	

The first column exhibits the length of the bar, in clear feet, between the supports.

The second expresses the weight of the bar in pounds, on the second day after it was felled, as evinced by experiments performed on two bars of each sort. Each of the first three pairs consisted of two cuts of the same tree. The one next the root was always found to be the heaviest, and Buffon uniformly observed, that the heaviest was constantly the strongest, and recommends this particular as a sure rule for the choice of timber. He observes, also, that this always proved to be the case when the timber, by growing vigorously, had formed very thick annual layers; but this circumstance takes place only during the advances of the tree, to a state of maturity, because the strengths of the different circles, approach in a gradual manner to equality, during the tree's healthy growth, when they decrease in these parts in a contrary manner.

The third column, represents the number of pounds required to break the tree, in the course of a few minutes.

The fourth column, points out the number of inches in which a tree bends down before breaking.

The fifth column, shews the time at which it broke.

The experiments made on other sizes, were conducted in a similar way. All the beams were formed square, and their sizes in inches are signified at the head of the columns, in the following table. In the first column are expressed their lengths in feet.

	4	5	6	7	8	A
7	5312	11525	18950	32200	47649	11525
8	4550	9787	15525	26050	39750	10085
9	4025	8308	13150	22350	32800	8964
10	3612	7125	11250	19475	27750	8068
12	2987	6075	9100	16175	23450	6723
14		5300	7475	13225	19775	5763
16		4350	6362	11000	16375	5042
18		3700	5562	9245	13200	4482
20		3225	4950	8375	11487	4034
22		2975				3667
24		2162				3362
28		1775				2881

M. Buffon, in order to effect uniformity in his experiments, had all his trees felled in the same season of the year, squared the day after, and operated on the third day, when he found also, that the strength of oak timber diminished much in the course of drying.—After a piece of this green timber had been placed in the situation required for the experiment, and weights nearly sufficient to break it were applied with briskness, a very sensible smoke was perceived to issue from its two ends, with a sharp hissing noise, which continued during the whole of the time the tree was bending and cracking. This result undeniably proved, that the whole length of the tree was strained, (which may be inferred, indeed from its bending through its whole length,) and, nothing, perhaps, could evince in a stronger manner,

manner the powerful effects of compression.

The experiments made by our philosopher on the five inch bars, he considered as his standard of comparison, and he accordingly prosecuted his enquiries to a greater extent, on pieces of this dimension.

The deductions derivable from the theory which has been adopted, would make us think that the relative strength of bars of the same section, is inversely as their lengths; but Buffon's experiments (excepting those in the first column), deviated very considerably from this rule. For instance, by referring to the last table, we perceive that the strength of the bar 28 feet long and 5 inches square, is 1775; and that the strength of a bar 5 inches square, and 14 feet long, is by the same table 5300; but we know that the strength of the 14 feet bar ought to be double that of 28 feet, in which case the strength of the latter bar in this, would be 2650, whereas it is only 1775. Again, the bar of 7 feet ought to possess double the strength of that of 14 feet, but this is not the case, for the strength of the latter is 5300, whereas half the strength of the former is 5762·5. In like manner, the strength of the 8 feet bar ought to be treble that of the 24 feet, whereas the strength of the latter is 2162, while one-third of the strength of the former is 3262 3. So also the strength of the 7 feet bar ought to be four times that of the 28 feet bar, but the strength of the latter we perceive is only 1775, while one fourth of the strength of the former is 2881. The column A specifies the strength which by the theory, each of the five inch bars ought to have exhibited.

The foregoing defect seems to prevail in all the experiments from the first to the last; it may be observed also in the experiments of Belidor, as well as in all those we have noticed, from whence we may conclude that it is a law of nature, depending on the true principles of cohesion, and the invariable operations of mechanics.

But still the difficulty is inexplicable; for the only effect produced by the length of a beam, is an increase of the strain at the section of fracture, arising from the operation of the intervening beam as a lever; though we cannot see clearly how the mode of action of the fibres in this section is effected, so as to change either their cohesion or the situation of its centre of effort; and yet something of the kind must happen.

There are certain circumstances, however, which must contribute to render a smaller weight sufficient, (as in the experiments of Buffon,) to break a long beam, than in the exact inverse proportion of its length; for the weight of the beam itself increases the strain as much, as if half of it were added to the strain, and operated on it as a farther weight. The weight of every beam on which Buffon performed his experiments, was very nearly 74 pounds per each cubic foot; but these beams were by far too small, to account, in a satisfactory way, for the deviation from the theory. Even the half weights of the 5 inch beams, whose respective lengths were 28, 14, and 7 feet, were only 182, 92 and 45 pounds, which rendered the actual strains in the experiments 11560, 5390, and 1956; but these, it is evident, deviate considerably from the before mentioned proportions of the beams, 4, 2 and 1.

Buffon observes, that healthy trees are universally strongest at the root end; of course when a long beam is made use of, its middle point, where the fracture takes place in the experiment, is situated in a weak (perhaps the weakest) part of the tree. The trials nevertheless of the 4 inch beams, proved that the difference arising from this cause is almost insensible.

Again, it is probable, that the relative strength of beams decreases faster than the inverse ratio of their lengths; we have, already observed, that when a weight operates on the middle of a beam so as to break it, its whole length is affected, and therefore a certain definite curvature of a beam, of a given form, is always accompanied by rupture. Let us suppose two beams, whose lengths are respectively 10 and 20 feet, to be bent to the same degree, at their places of fixture in a wall; and we shall find that the weight operating on the former is nearly double that which hangs on the latter.—But the form of any portion, of these two beams, (say for 5 feet immediately adjoining to the wall,) differs considerably, since the curvature of the first beam at this distance, is only one half of its curvature at the wall, while the curvature of the latter in the corresponding part, is three-fourths of the same curvature at the wall. Hence, therefore, through the whole of the intermediate space of 5 feet, the curvature of the former is less than that of the latter, and consequently the latter beam must be weaker throughout. It likewise occasions the fibres of the beam to slide more on each other, whereby their lateral union is effected; and therefore those possessed of greater degrees of strength will not render assistance to those that have less. In addition to this, the force with which the fibres of shorter beams are pressed laterally on each other, is double, and must of course impede the mutual sliding of the fibres. In fact this lateral compression is not only calculated to change the law of longitudinal cohesion, but to increase the strength of the very surface of fracture.

It is much to be desired, that the engineer would carefully remember, that a beam of quadruple length, instead of possessing one fourth of the strength, has only about one sixth; and the ingenious theorist should enquire into the nature, as well as the cause of this diminution, in order that he may be enabled to furnish the mechanic, with a more accurate rule for computation.

Our want of an intimate acquaintance with the law, by which the cohesion existing between particles is changed by an alteration of distance; deprives us of the means of discovering the precise relation

relation which exists between the curvature and the momentum of cohesion, and in order to obtain some rules whereby the strengths of different solids may be calculated, it will be necessary to multiply experiments. The experiments of Buffon furnish us, however, with considerable assistance in this particular. If we select, for instance, any number in the column of the 5 inch beams, and add to it the sum of half the weight of the beam, with the constant number 1245, a set of numbers will be given very near the reciprocals of the lengths. From this we may readily deduce a convenient formula, very easy to be remembered.

Let the length of the beam of 5 inches square be designated by a, the number 1245 by m, and the weight known to break the beam by w, then we shall have $\frac{(w+m)a}{l} - m = p$. Thus, the weight required to break the 7 foot bar, is 11525 and let l be 18, then we shall have $\frac{(w+m)a}{l} - m =$

$\frac{(11525+1245)7}{18} - 1245 = 3720 = p$, which differs about $\frac{1}{40}$ from the result furnished us by that experiment. This formula may be applied with success to all the other lengths, except those of 10 and 24 feet. Although this formula cannot be admitted as universally true, yet it will be found to be tolerably correct in a great variety of lengths.

We will next consider the relation that exists between the strength and the square of the depth of the section. By comparing the numbers in any horizontal row of the table, we shall perceive on trial, that the numbers of the five inch bars are uniformly greater than those of the rest. If the numbers, however, in this column be omitted, or uniformly diminished about one-sixteenth, as to their strength, the different sizes will be found to differ but little from the ratio of the square of the depth, as determined by theory; though we should observe that a small deficiency takes place in the larger beams.

Our next enquiry will be directed to the absolute cohesion and the relative strength. The values deducible from experiments on absolute strength, must be confined to very small pieces, in consequence of the very great force which is required to tear them asunder. The whole we can furnish on this head for the consideration of our readers, are two passages extracted from Muschenbroek's "*Essais de Physique*." In one of these passages he observes that a piece of sound oak $\frac{27}{100}$ of an inch square, was torn asunder by 1150 pounds; and in the other, that an oak plank one inch in thickness, and twelve inches broad, will suspend about 189462 pounds. We may conclude from these passages, that the cohesion of a square inch is 15755 and 15763 pounds. Bouguer, another experimentalist, observes that a rod of sound oak, one fourth of an inch square, will be torn asunder by a 1000 pounds, which furnishes the round number 16000, for the cohesion of a square inch.

It may not be unprofitable to the reader to compare those circumstances with the experiments made by Buffon on four inch beams.

The absolute cohesion of the before mentioned section is $16\times16000=256000$; were every fibre to exert its entire energy, at the moment in which the fracture takes place, the effect of the momentum of cohesion would be the same as if it had entirely acted at the centre of gravity of the section, at the distance of two inches from the axis of fracture, and therefore it is $256000\times2=512000$. We shall find by reference to the last table, that the beam 7 feet long and 4 inches square, was broken by a weight of 5312 pounds, suspended on its middle; but if it had been suspended at its extremity, projecting 42 inches from a wall, it would have been broken by one half of the foregoing weight; viz. 2656 pounds. The momentum of this strain is, $42\times2656=111552$; being in equilibrio with the actual momentum of cohesion, which is 111552 instead of 512000; consequently the strength is diminished in the proportion of 512000, to 111552, or nearly as 4·59 : 1.

The ignorance that prevails relative to the particular situation of the centre of effort, renders it altogether useless to consider the full cohesion that employs its energies, at the centre of gravity, and produces the momentum 512000; we may, however, convert the whole into a simple multiplier of the length, and say, *that n times the length is to the depth, as the absolute cohesion of the section is to the absolute strength.*

If, therefore, we represent in inches the breadth by b, the depth by d, the length by l, and the absolute cohesion of a square inch by s; the relative strength, or the external force p, which balances it, is in round numbers $\frac{b\ d^2\ s}{9\ l}$.

We cannot attribute this diminution of strength to any inequality of those cohesive forces which may be exerted at the instant of fracture; since we must know, from the centre of effort in a rectangular beam, being situated at one-third of the height, that the relative strength would be $\frac{b\ d^2\ s}{3\ l}$, and that p would be 8127 instead of 2656.

This great diminution may be ascribed to the compression of the under part of the beam; and we have before observed, that the forces actually exerted by the particles of a body, when stretched or compressed, are very nearly proportioned to the distances to which the particles are drawn from their natural positions; and though in cases of great compression

pression the forces may increase a faster ratio, yet this increase will produce no sensible change in the present question, because the body is broken before the compressions have proceeded so far: in fact, we may conceive that the compressed parts are crippled before the extended parts are torn asunder. Muschenbroek asserts this with a considerable degree of confidence, and says that although oak will suspend half as much again as fir, yet it will not support, as a pillar, two-thirds of the load which fir will support in that form.

The experiments of Buffon, furnish us with a useful practical rule, without our being obliged to rely on any value of the absolute cohesion of oak. From knowing that the strength is nearly as the breadth, and the square of the depth; and the inverse of the length, and taking for the sake of convenience the length of the beam in feet, and its breadth and depth in inches; and also knowing from the table, that a beam four inches square, and seven feet between the supports, is broken by 5312 pounds, we may conclude that a batten, one foot in length between the supports, and one inch square, will be broken by 581 pounds. Hence, the strength of any other oak beam, or the weight barely required to break it, when hung on its middle, is $581\ \frac{bd^2}{l}$, b, d and l, respectively representing the breadth, depth, and length.

In some of our former inquiries, we have found a considerable deviation from the inverse proportion of the length, and we must necessarily accommodate our rule to it. When the number 1245 was added to each of the numbers in the column of the five inch bars, a set of numbers was produced, which were very nearly reciprocals of the lengths; if we make a similar addition to the other columns, but in proportion to the cubes of their dimensions, we shall have nearly the same result. Hence, to find the necessary number, say, as $5^3 : 4^3 :: 1245 : 647$, the required number, this added to 5312, gives 5959, the 64th part whereof, we may call 93, which answers to a bar 7 feet long, and an inch square. Hence, 93×7, will be the reciprocal corresponding to a bar of one foot; this is 651, and after taking from it the present correction, which is $\frac{40\ b}{4\ b} = 10$, 641 will remain for the strength of the bar. From this result, we obtain the general rule $\frac{651\ b\ d^2}{l} - 10\,bd^2 = p$, which we may otherwise state in words, as follows, in order to render it clearer to those who are not versed in Algebra.

Multiply the breadth of the beam, in inches, twice by the depth, and this again by 651, and divide the whole by the length in feet. From the quotient, take 10 times the product, (which arises by multiplying the breadth of the beam, in inches, twice by the depth), and the remainder is the number of pounds required to break the beam.

Example.—Required the weight necessary to break an oak beam 16 feet long between the props, and seven inches square.

$$\text{Here, } p = 651 \times \frac{7 \times 7^2}{16} - 10 \times 7 \times 7^2 = 10526,$$

whereas the experiment gives 11000.

Example.—Required the weight necessary to break an oak beam, 12 feet long, between the props and six inches square.

$$\text{Here, } p = 651 \times \frac{6 \times 6^2}{12} - 10 \times 6 \times 6^2 = 9558,$$

while the experiment furnishes us only with 9100.

Example.—It is required to determine the weight barely necessary to break an oak beam 20 feet long between the props, and five inches square.

$$\text{Here } p = 651 \times \frac{5 \times 5^2}{20} - 10 \times 5 \times 5^2 = 3818,$$

while the table exhibits only 3225.

We may compare, in a like manner, any other dimension; but we shall find that the rule is most deficient when applied to the five inch bars, which, we have before observed, appear stronger than the rest.

The sure way of applying the foregoing rule, is to suppose the beam square, by increasing or diminishing its breadth, till it becomes equal to its depth; then find the strength, by this rule, and increase or diminish it agreeably to the change which has taken place in its breadth, when there can be no doubt, that the strength of the beam, given as an example, will be double that of a beam of the same depth, and half the breadth.

It may be necessary, perhaps, to remind the reader, that the whole of the preceding calculations and observations, are founded on the supposition, that the weight applied is the greatest which a beam will bear for a very few minutes. Buffon observes, that two-thirds of this weight, will sensibly impair the strength of the beam, and indeed will frequently break it, if permitted to operate continually, for two or three months. One half bent the beam when applied only for a few minutes, but though, as he observes, this weight may be borne by it, for any length of time, still the beam will contract a certain curvature, from which it will not easily get into its pristine state. One third seemed to produce no permanent effect on the beam, which recovered its original shape, even after it had been kept loaded for several months. But this depends on the pieces being seasoned, for a piece just felled, will break under one fourth of a given weight, while a third of the same weight may be laid on the well seasoned piece, for any length of time, without giving the beam a sett.

We are destitute of experiments on the strength of other kinds of timber. M. Buffon, says, that fir possesses

possesses about $\frac{4}{5}$ths of the strength of oak. Parent, however, asserts, that it possesses $\frac{5}{6}$ths; while Emerson, says it has $\frac{2}{3}$ds.

Before we conclude our enquiries into this particular strain, we would wish to impress on the minds of practical men in general, the necessity of avoiding transverse strains, as much as possible, since the injury that many structures have sustained from their influence is incalculable.

BODIES MAY BE WRENCHED OR TWISTED.

The species of strain operates on all axles which connect with the working, or moveable parts of machines.

The resistance occasioned by this species of strain, must be proportioned to the number of particles, when all the particles act alike.

In proof of this, let E F C D represent a body possessing insuperable strength, but cohering in a weaker manner in the common surface A B which separates the body into two parts, viz. ABCD, ABFE: then, if one part, as ABCD is supposed to be pushed laterally in the direction A B, it becomes evident that it can only yield there, and that the resistance produced will be proportioned to the surface.

The same result will take place, if we suppose a thin cylindrical tube to be twisted in contrary directions, in which case it will undoubtedly fail first in that section where the cohesion of the fibres is the least. This section forms the circumference of a circle, for which reason the particles composing the two parts contiguous to this circumference, will be drawn from each in a lateral direction; and the total or absolute resistance, will be as the number of particles exhibiting an equal degree of resistance, which is in fact, the circumference. Within the circumference to which we have just alluded, let us conceive a series of tubes till they reach the centre. Now if the particles composing each of these tubes, exerted a similar degree of force, the resistance offered by each ring of the section would be as its circumference and its breadth, (which we will suppose to be indefinitely small) the entire resistance would be as the surface; and this would represent the resistance of a solid cylinder. But the external parts of a cylinder when twisted by the application of an external force applied to its circumference, will suffer a greater circular extension than the internal, and it appears that this extension will bear a proportion to the distance of the particles from the axis. This proportion would seem to be very probable, and if it really exist, the forces simultaneously exerted by each particle, will be as their several distances from the axis. Consequently, the entire force exerted by each ring will be as the square of its radius, and the accumulated force actually exerted, will be as the cube of that radius.

By referring to *Figure* 23, we shall have the accumulated force exerted by the whole of a cylinder, whose radius is A C, is to the accumulated force exerted, at the same by the part whose radius is C E as A C^3 to C E^3.

The whole cohesion exerted in this instance, is just two thirds of what it would be if all the particles exerted the same attractive forces, as are exerted by the particles in the external circumference.

This will appear evident, if we first suppose the rectangle A C c a to be erected in a position perpendicular to the plane of the circle, along the line AC, and then, that it is permitted to revolve round the, C c. This rectangle, by its motion, will generate a cylinder, whose height will be denoted by C c or A a, which will have the circle K A H for its base. Next if the triangle C c a be likewise permitted to perform a revolution around the line C c, it will describe the surface of a cone. Now the cylindrical surface supposed to be generated by Aa, will represent the whole cohesion exerted by the circumference A H K; the cylindrical surface generated by E e, will shew the cohesion exerted by the circumference E L M; the solid generated by the triangle C A a will display the cohesion exerted by the entire circle A H K; and the cylinder generated by the rectangle A C c c will exhibit the measure of the cohesion exerted by the same surface, supposing each particle to suffer the extension A a.

It is evident, in the first instance, that the solid produced by revolution of the triangle C E e, is to that generated by A a C, as E C^3 to A C^3. In the next instance, the solid generated by A a C is two-thirds of the cylinder, because the cone generated by C c a, forms one-third of it.

It may now be supposed, that the cylinder may be twisted so powerfully, that the particles, situated in the exterior circumference, must lose their cohesion, when little doubt can be entertained, that it will be wrenched asunder, in consequence of all the inner circles giving way in succession. If we admit this, then a body, the texture of which is homogeneous will resist a simple twist with two-thirds of the force with which it would resist it, if an attempt were made to force one part laterally from the other, or with one-third part of the force which will cut it asunder by a square edged tool.

When two cylinders are wrenched asunder, we must, of necessity, conclude, that the external particles of each are placed just beyond their limits of cohesion, that they are extended equally, and operate with equal forces; from whence it follows, that in the instant of fracture the entire sum of the forces actually exerted, is as the squares of the diameters.

The real strength of the section, and the relation it bears to its absolute lateral strength being now ascertained, our next business is to enquire into its strength, as it relates to the external force which may be employed to break it.

The straining force and the cohesion oppose each other, on the principle of levers; and the centre

tre of the section may be the neutral point, the position of which is not disturbed. Let r represent the radius of the cylinder f, the force exerted laterally by an exterior particle, x the indeterminate distance of any circumference, and $\dot{x}$, the infinitely small interval between the concentric arches. Now the forces being as the extensions, and they being as their distances from the axis, the cohesion, actually exerted at any part of the ring, will be $\frac{f x \dot{x}}{r}$; the force exerted by the entire ring $\frac{f x^2 \dot{x}}{r}$; and the momentum of cohesion, (which, in any ring, is as the force multiplied by its lever) will be $\frac{f x^3 \dot{x}}{r}$. Consequently, the accumulated momentum will be $\int \frac{f x^3 \dot{x}}{r} = \frac{f x^4}{4 r}$ and when x, becomes equal to r, it will be $\frac{f r^4}{4 r} = \frac{f r^3}{4} = \frac{1}{4} f r^3$.

From hence we learn, that the particular strength of an axle, by which it resists being wrenched asunder, by a force acting at a given distance from the axis, is as the cube of the diameter.

Again, the expression $\frac{1}{4} f r^3$, may be decomposed into the factors $f r^2 \times \frac{1}{4} r$, the former of which, $f r^2$ expresses the full lateral cohesion of the section; while the momentum thereof, is the same as if the full lateral cohesion were accumulated at a point, distant from the axis, one fourth of the radius of the cylinder.

Let d denote the measure of the diameter of the cylinder in inches, f the number of pounds which measure the lateral cohesion of a circular inch, l the length of the lever, by which the straining force represented by p, is supposed to act, and we shall have $\frac{f d^3}{8} = p l$, from which may be deduced, $p = \frac{f d^3}{8 l}$.

In general, therefore, the particular strength which enables an axle to resist its being wrenched asunder by twisting, is as the cube of its diameter.

The interior parts do not act so powerfully as the exterior, for if a hole be bored out of an axle, equal in size to one half of its diameter, the strength will be diminished only one eighth, while the quantity of matter will decrease one fourth; from whence it follows, that hollow axles are stronger than solid ones, containing the same quantity of matter.

The propriety of Engineers introducing this very important improvement into their machines, becomes now very obvious, since the parts, so constructed, have not only the advantage of being much stiffer, but they furnish much better means for fixing the flanches made use of to connect them with the wheels or levers, by which they are turned and strained.

We shall now introduce to the notice and observation of the student, a variety of propositions and deductions, chiefly selected from Emerson's excellent treatise of Mechanics.

Proposition.—If a beam of timber, (*Figure* 1, *Plate* 15,) be supported at C and B, lying upon the wall, A C E, with one end, and if G be the centre of gravity of the whole weight sustained; and the line F G H, be drawn perpendicular to the horizon, and C F, and B H, to C B; and B F, drawn; I say,

The weight of the whole body	F H.
Pressure at the top C,	B H,
Thrust or pressure at the base B	F B,
are respectively as	and in these several directions."

If the beam support any weight, the beam and weight must be considered as one body, whose centre of gravity, is G. Then the end C is supported by the plane B C E; and the other end B may be supposed to be sustained by a plane perpendicular to B F; therefore the weight and forces at C and B, are respectively as F H, B H, and B F."

"*Cor.* 1.—Produce F B towards Q, then B Q is the direction of the pressure at B; and the pressures at B in the directions B Q, F D, D B, are as F B, F D, D B."

"*Cor.* 2.—Draw D r perpendicular to B C, and draw C D, then the weight, pressure at the top, direct pressure at bottom, and horizontal pressure at bottom, are respectively as C B, B D, D C, and D r."

"For since the angles B C F, B D F, are right; a circle described upon the diameter B F, will pass through C D. Therefore ∠B C D = B F D standing on the same arch BD, and because the ∠ G B H and ∠ S at D are right, B H F = C B D; therefore, the triangles F H B, and C B D are similar, and the figure B H D F similar to the figure D B r C, whence F H : B H : B F : B D : are as C D : B D : D C : and Dr."

"*Cor.* 3.—All this holds true for any force instead of gravity, acting in direction G D."

Proposition.—If B C, *fig.* 2, be any beam bearing any weight, G the centre of gravity of the whole: and if it lean against the perpendicular wall C A, and be supported in that position; draw B A, C F parallel, and F G D perpendicular to the horizon, and draw F B, then

The whole weight	F D
Pressure at the top C	B D
Thrusts or pressure at the bottom	F B
B are respectively as	and in the same directions"

Fo

"For the end C is sustained by the plane A C; and if the end B be supposed to be sustained by a plane perpendicular to F B; then the weight, and pressure at top and bottom, are as D F, D B, F B. If you suppose the end B is not sustained by a plane perpendicular to F B, the body will not be supported at all."

"*Cor.* If F B be produced to Q, then B Q is the direction of the pressure at B: and the perpendicular pressure at B (F D) is equal to the weight; and the horizontal pressure at B (B D), is equal to the pressure against C."

"*Proposition.*—If a heavy beam, or one bearing a weight be sustained at C, (*Figure* 3,) and moveable about a point C; whilst the other end B lies upon the wall B E, and if H G F be drawn through the centre of gravity G, perpendicular to the horizon, and B F, C H, perpendicular to B C, and C F be drawn; then

The whole weight	H F
Pressure at B	H C
Force acting at C	C F,
are respectively as	and in these directions."

"For the end B is sustained by the plane C B, and the end C may be supposed to be sustained by a plane perpendicular to F C, or by a cord in direction C F. Then since H C is parallel to B F, the weight, force at C, pressure at B, are respectively as H, F C F, H C."

"*Cor.* But if, instead of lying upon the inclined plane at B, the end B be laid upon the horizontal plane A B, then the weight and the pressure at B and C, are respectively as B C, G C, and B G; and in this case there is no lateral pressure."

"For B F will be perpendicular to B A, and parallel to H F, and consequently C F is also parallel to H F, therefore the forces at C, G, B, are as B G, B C, and C G."

Proposition.—If a heavy beam B C, (*Figure* 4) whose centre of gravity is G, be supported upon two posts B A, C D; and be moveable about the points, A, B, C, D, and if A B, D C, produced, meet in any point H, of the line G F drawn perpendicular to the horizon; and if from any point F, in the line G F, F E, be drawn parallel to A B; I say,

The whole weight	H F
Pressure at C	H E
Thrust or pressure at B,	E F,
are respectively as	and in these directions"

For the points A, B, C, D, being in a plane perpendicular to the horizon, the body may be supposed to be supported by two planes at B, C, perpendicular to A B, D C; or by two ropes B H, C H; and in either case, the weight in direction H G, the pressure at B, C, in directions H B, H C, are as H F, E F, and H E.

Cor. Hence, whether a body be sustained by two ropes, B H, C H, or by two posts A B, C D. or by two planes perpendicular to B A, C D; the body then can only be at rest, when the plumb line H G F, passes through G, the centre of gravity of the whole weight sustained, or which is the same thing, when A B, D C, intersect in the plumb-line H G F, passing through the centre of gravity."

SCHOLIUM.

"By the construction of these four last propositions, there is formed the triangle of pressure, representing the several forces. In which, the line of gravity (or plumb line passing through the centre of gravity,) always represents the absolute weight, and the other sides, the corresponding pressures."

Proposition.—If several beams A B, B C, C D, &c. *Figure* 5, be joined together at B, C, D, &c. and moveable about the points A, B, C, &c. be placed in a vertical plane, the points A, F, being fixed, and through B, C, D, drawing r i, s m, t p, perpendicular to the horizon, and if several weights be laid on the angles B, C, D, &c. so that the weight on any angle C, may be as $\frac{S.BCD}{S.mCB \times S.mCD}$, then all the beams will be kept in equilibrio by these weights."

Produce D C to r. Then S. $\angle$ A B C : S. $\angle$ A Br : : weight B : force in direction BC $= \frac{B \times S.ABr}{S.ABC}$ and S.B C D : S.D C s : : weight : force in direction C B $= \frac{C \times S.DCs}{S.BCD}$; which, to preserve the equilibium, must be equal to the force in direction B C, that is, $\frac{B \times S.ABr}{S.ABC} = \frac{C \times S.DCs}{S.BCD}$; whence, B : C : : $\frac{S.ABC}{S.ABr}$: $\frac{S.BCD}{S.DCs}$. And by the same way of reasoning, C : D : : $\frac{S.BCD}{S.BCs}$: $\frac{S.CDE}{S.EDt}$. Therefore, *ex equo*, weight B : weight D : : $\frac{S.ABC}{S.ABr \times S.BCs}$: $\frac{S.CDE}{S.DCs \times S.EDt}$: : $\frac{S.ABC}{S.ABi \times S.CBi}$: $\frac{S.CDE}{S.CDp \times S.EDp}$

Cor. 1.—Produce C D, so that D w, may be equal to C r, and draw w x, parallel to D p, cutting D E, in x, then the weight C, the forces in directions C B, and C D, are as r B, C B, and C r, respectively, and the weight C, is to the weight D, as B r to w x."

"*Cor.* 2.—The force, or thrust, at C, in direction CB, or at B, in direction BC, is as the secant of the elevation of the line B C, above the horizon."

"For, force in direction C B : force in direction C D : : C B : C r : : S. C r B, or r C m, or s C D : S. r B C : : cos. elevation of C D : cos. elevation of C B : : sec. elevation of C B : sec. elevation CD, because the secants are reciprocally as the cosines."

"*Cor.*

" *Cor.* 3.—Draw C p, D m, parallel to D E, C B, then the weights on C and D, to preserve the equilibrium, will be as C m to D p, and therefore, if all the weights are given, and the position of two lines C D, D E, then the positions of all the rest C B, B A, &c. will be successively found. For let the force in direction C D, or D C, be C D, then C p is the force in direction D E, and D m, in direction C B. And D p, or the weight D, is the force compounded of D C, C p; and C m, or the weight C, is the force compounded of C D, D m."

" *Cor.* 4.—If the weights lie not on the angles B, C, D, &c. let the places of their centres of gravity be at g, h, k, l, and let g, h, k, l, also express their weights. And take the weight B $=$
$\frac{A\,g}{A\,B}\,g + \frac{h\,C}{B\,C}\,h$, C $= \frac{B\,h}{B\,C}\,h + \frac{k\,D}{C\,D}\,k$, D $= \frac{C\,k}{C\,D}\,k + \frac{l\,E}{D\,E}\,l$, &c. then B, C, D, &c. will be the weights lying upon the respective angles."

" *Cor.* 5.—If the weights were to act upwards, in the directions m C, p D, &c, or which is the same thing, if the figure A, B, C, D, E, F, was turned upside down, and the weights remain the same, and the points A F, be fixed as before. All the angles at B, C, D, &c. and consequently the whole figure will remain the same as before; and that whether the lines A B, B C, C D, &c. be flexible or inflexible cords or timbers."

" This will easily appear, by the demonstration of the prop. For the ratio of the forces at any angle C, will be the same, whether they act towards the point C, or from it; that is, it will be the same thing, whether the weight at any angle C, acts in direction C m, or C s, and as the forces were supposed before to thrust against C, the same forces now do pull from it."

" *Scholium.*—If D A, B F, *Figure* 6, be a semicircle, whose diameter is D F, draw A G, perpendicular to D F, then the force or weight at any place A, to preserve the equilibrium, will be reciprocally as $A\,G^3$, or directly as the cube of the secant of the arch B A."

" Likewise it follows from *Cor.* 5, that if any cords of equal lengths, be stretched to the same degree of curvature, the stretching forces will be as the weights of the cords."

Proposition.—If the distance of the walls A D and B C be given, *Fig.* 7, and A B, A C be two beams of timber of equal thickness; the one horizontal, the other inclined; and if two equal weights P, Q, be suspended in the middle of them; the stress is equal in both, and the one will as soon break as the other, by these equal weights."

" For A C : A B : : weight P : $\frac{A\,B}{A\,C}$ P $=$ pressure against the plane, or part of the weight the beam A C sustains. And the stress upon A C is $\frac{A\,B}{A\,C}$ P $\times$ A C or A B $\times$ P; and the stress on A B is Q $\times$ A B, which is equal to A B $\times$ P, because the weights P, Q are equal. Therefore, the stress being the same, and the beams being of equal thickness, one will bear as much as the other, and they will both break together."

" *Cor.* 1 If the beams be loaded with weights in any other places in the same perpendicular line as F, G; they will bear equal stress, and one will as soon break as the other."

" For they are cut into parts similar to one another; and therefore stress at F : stress by P : : A F C : A C^2 : : A G B : $\frac{A\,B^2}{4}$: : stress by B : stress by Q or stress by P. Therefore stress at F $=$ stress at B."

"*Cor.* 2. If the two beams be loaded in proportion to their lengths; the stress by these weights, or by their own weights, will be as their lengths; and therefore the longer, that stands a slope, will sooner break."

" For the stress upon A C was A B $\times$ P, and the stress on A B was A B $\times$ Q; but since P and Q are to one another, as A C and A B, therefore the stress on A C and A B will be as A B $\times$ A C and A B $\times$ A B; that is, as A C to A B. And in regard to their own weights, these are also proportional to their lengths."

" *Proposition.*—Let A B, A C, *Figure* 8, be two beams of timber of equal length and thickness, the one horizontal, the other set sloping, if C D be perpendicular to A B, and they be loaded in the middle with two weights, P, Q, which are to one another as A C to A D, then the stress will be equal in both, and one will as soon break as the other."

" For A C : A D : : P : $\frac{A\,D}{A\,C}$ P $=$ pressure of P in the middle of A C. And by supposition, A C : A D : : P : Q; therefore $\frac{A\,D}{A\,C}$ P $=$ Q, the weight in the middle of A B. Therefore the forces in the middle of the two beams are the same, and the lengths of the beams being the same, therefore the stress is equal upon both of them; and being of equal thickness, if one breaks, the other will break."

" *Cor.* If the weights P, Q, be equal upon the two equal beams A B, A C, the stress upon A B will be to the stress upon A C, as A B or A C to A D, the same holds in regard to their own weights."

For the weight Q is increased in that proportion.

" *Proposition.*—If several pieces of timber be applied to any mechanical use where strength is required, not only the parts of the same piece, but the several pieces in regard to one another, ought to be so adjusted for bigness, that the strength may be always

ways proportional to the stress they are to endure."

This proposition, Mr. Emerson observes, is the foundation of all good mechanism, and ought to be regarded in all sorts of tools and instruments we work with, as well as in the several parts of any engine; for who that is wise, will overload himself with his work tools, or make them bigger and heavier then the work requires? Neither ought they to be so slender as not to be able to perform their office. In all engines, it must be considered what weight every beam is to carry, and proportion the strength accordingly. All levers must be made strongest at the place where they are strained the most; in levers of the first kind, they must be strongest at the support; in those of the second kind, at the weight; in those of the third kind, at the power, and diminish proportionally from that point. The axles of wheels and pullies, the teeth of wheels, which bear greater weights, or act with greater force, must be made stronger, and those lighter, that have light work to do. Ropes must be so much stronger or weaker, as they have more or less tension; and in general, all the parts of a machine must have such a degree of strength, as to be able to perform its office, and no more; for an excess of strength in any part does no good, but adds unnecessary weight to the machine, which clogs and retards its motion, and makes it languid and dead. And on the other hand, a defect of strengh where it is wanted, will be a means to make the engine fail in that part, and go to ruin. So necessary it is to adjust the strength to the stress, that a good mechanic will never neglect it; but will contrive all the parts in due proportion, by which means they will last all alike, and the whole machine will be disposed to fail all at once. And this will ever distinguish a good mechanic from a bad one, who either makes some parts so defective, imperfect, and feeble, as to fail very soon; or makes others, so strong or clumsy, as to out-last all the rest."

"From this general rule follows,

"*Cor.* 1.—In several pieces of timber of the same sort, or in different parts of the same piece; the breadth multiplied by the square of the depth, must be as the length, multiplied by the weight to be borne, for then the strength will be as the stress.

"*Cor.* 2.—The breadth multiplied by the square of the depth, and divided by the product of the length and weight, must be the same in all."

"*Cor.* 3.—Hence, may be computed the strength of timber, proper for several uses in building. As,

"First.—To find the dimensions of joists and boards for flooring. Let b, d, l, be the breadth, depth, and length, of a joist, n, = the number of them, x = their distance, g = the depth of a board, w = the weight, then $n\,b\,d^2$ = the strength of all the joists, and $w\,l$ = the stress on them, also, $n\,l\,g^2$ = the strength of the boards, and $w\,x$, their stress; therefore, $\frac{n\,b\,d^2}{w\,l} = \frac{n\,l\,g^2}{w\,x}$; and, $x = \frac{l^2\,g^2}{b\,d^2}$ for the distance of the joists, or the length of a board between them. Or $b = \frac{l^2\,g^2}{d^2\,x}$, or $d^2 = \frac{l^2\,g^2}{b\,x}$, and so on, according to what is wanted."

Secondly.—To find the dimensions of square timber for the roof of a house,—Let r, s, l, be the length of the ribs, spars, and lats, so far as they bear; x, y, z, their breadth or depth, n, the distance of the lats, w = the weight upon a rib, c = the cosine of elevation of the roof. Then by reason of the inclined plane $\frac{l\,w}{r} \times c$ = the weight upon a spar. And $\frac{l\,n\,w}{r\,s}$ = the weight upon a lat, for the ribs and lats lie horizontally. Therefore, $\frac{x^3}{w \cdot r} =$

$$\frac{y^3}{\frac{s\,l\,w}{r} \times c} = \frac{z^3}{l \times \frac{l\,n\,w}{r\,s}}.$$

Whence, $x^3 = \frac{r^2\,y^3}{c\,l\,s}$, and $x^3 = \frac{r^2\,s\,z^3}{l^2\,n}$.

Hence, if any one x, y, or z, be given, and all the rest of the quantities; the other two may be found. Or in general, any two being unknown, they may be found, from having the rest given."

"For example.—Let r = 9 feet, s = 4 feet, l = 15 inches, n = 11 inches, c = 707, the cosine of 45° the pitch of the roof. And assume y = 2½ inches, then x $= 2\frac{1}{2}\left(\frac{81}{3\cdot535}\right)^{\frac{1}{3}} = 7\cdot1$ inches, and $z = 2\frac{1}{2}\left(\frac{55}{543}\right)^{\frac{1}{3}}$ $= 1\frac{1}{6}$ inches."

"*Proposition.*—If any weight be laid on the beam A B, as at C, *(see Figure 9, and 10,)* or any force applied to it at C, the beam will be bent through a space C D, proportional to the weight or force applied at C; and the resistance of the beam will be as the space it is bent through nearly."

"In order to find the law of resistance of beams of timber, or such like bodies, against any weights laid upon them, or straining them, I took a piece of wood planed square, and supporting it at both ends A, B, I laid successively on the middle of it at C, 1, 2, 3, 4, 5, 6, 7, and 8 pounds; and I found the middle point C to descend through the spaces 1, 2, 3, 4, 5, 6, 7, and 8 respectively. And repeating the same experiment with the weights 3, 6, 9lbs. they all descended through spaces, either accurately or very nearly as the numbers 1, 2, 3. I tried the same things with springs of metal, and found the space through which they were bent, proportional to the weight suspended. I also tried several experiments of this kind with wires, hairs, and other elastic flexible bodies, by hanging weights at them; and

and I found that the increase of their lengths, by stretching, was in each of them proportional to the weights hung at them; except when they were going to break, and then the increase was something greater. It may be observed, that none of these bodies regained their first figure, when the weights were taken off, except well tempered springs; so that there are no natural bodies *perfectly* elastic. And even springs are observed by experience to grow weaker by often bending; and by remaining some time unbent, will recover part of their strength; and are something stronger in cold than in hot weather. But at any time, a spring, and all such bodies observe this law, that they have the least resistance when least bent, and in all cases are bent through spaces nearly proportional to the weights or forces applied. And, therefore, I think this law is sufficiently established, that the resistance any of these bodies makes, is proportional to the space through which it is bent, or that it exerts a force proportional to the distance it is stretched to."

"The knowledge of this property of springy bodies is of great use in mechanics, for by this means a spring may be contrived to pull at all times with equal strength, as in the fusee of a watch; or it may be made to draw in any proportion of strength required."

"The action of a spring may be compared to the lifting up a chain of weights, lying upon a plane, or to the lifting a cylinder of timber out of the water endways."

This author farther observes, that "the propositions before laid down concerning the strength and stress of timber, &c. are also of excellent use in several concerns of life, and particularly in Architecture; and upon these principles a great many problems may be resolved, relating to the due proportion of strength in several bodies, according to their particular positions and weights they are to bear, some of which I shall briefly enumerate."

"If a piece of timber is to be holed with a mortice hole, the beam will be stronger when it is taken out of the middle, than if it be taken out of either side. And in a beam supported at both ends, it is stronger when the hole is taken out of the upper side than the under one, provided a piece of wood is driven hard in to fill up the hole."

"If a piece is to be spliced upon the end of a beam to be supported at both ends, it will be stronger when spliced on the under side of a beam, than on the upper side. But if the beam is supported only at one end, to bear a weight on the other, it is stronger when spliced on the upper side."

"When a small lever &c. is nailed to a body to remove it, or suspend it by, the strain is greater upon the nail nearest the hand, or point where the power is applied."

"If a slender cylinder, is to be supported by two pieces, the distance of the pins ought to be $\frac{5858}{1000}$ parts of the length of the cylinder, that is $\frac{4}{5}$ its length, the pins equidistant from its ends, and then the cylinder will endure the least bending or strain by its weights."

"By the same principles, if a wall faces the wind, and if the section of it be a right angled triangle, or the foreside be perpendicular to the horizon, and the backside terminated by a sloping plane intersecting the other plane in the top of the wall, such a wall will be equally strong in all its parts to resist the wind, if the parts of the wall cohere strongly together; but if it be built of loose materials, it is better to be convex on the backside, in form of a parabola."

"If a wall is to support a bank of earth, or any fluid body, it ought to be built concave in form of a semi-cubical parabola, whose vertex is at the top of the wall; this is when the parts of the wall stick well together; but if the parts be loose, then a right line or sloping plane ought to be its figure. Such walls will be equally strong throughout."

"All spires of churches in the form of cones or pyramids, are equally strong in all parts to resist the wind; but when the parts cohere not together, parabolic conoids are equally strong throughout."

"Likewise, if there be a pillar erected in the form of the logarithmic curve, the assymptote being the axis, it cannot be crushed to pieces in one part sooner than in another, by its own weight. And if such a pillar be turned upside down, and suspend at the thick end in the air, it will be no sooner pulled asunder in one part than another by its own weight. And the case is the same if the small end be cut off, and instead of it, a cylinder be added, whose height is half the subtangent."

The same author states also his having found by experience, that there is a great deal of difference in strength, in different pieces of the very same tree, some pieces I have found would not bear half the weight that others would do. The wood of the boughs and branches is far weaker than that of the body; the wood of the great limbs is stronger than that of the small ones, and the wood in the heart of a sound tree is the strongest of all. I have also found by experience, that a piece of timber, which has borne a great weight for a small time, has broke with a far less weight, when left upon it for a longer time. Wood, is likewise, weaker when it is green, and strongest when thoroughly dried, and should be two or three years old at least. If wood happens to be sappy it will be weaker upon that account, and will likewise decay sooner. Knots in wood weaken it very much, and this often causes it to break where a knot is, Also when wood is cross-grained, as it often happens in sawing: this will weaken it more or less, according as it runs more or less cross the grain. And I have found by experience, that tough wood cross the grain, such as elm or ash is 7, 8 or 10 times weaker than straight; and wood that easily splits

splits, such as fir, is 16, 18, or 20 times weaker. And for common use it is hardly possible to find wood but it must be subject to some of these things. Besides when timber lies long in a building, it is apt to decay, or to be worm eaten, which must needs very much impair its strength. From all which it appears, that a large allowance ought to be made for the strength of wood, when applied to any use, especially where it is designed to continue for a long time."

We come next, to some observations and examples of that ingenious experimental philosopher Mr. John Banks, contained in his useful treatise on the "*Power of Machines*." which work we strongly recommend to the attention of mechanics in general.

This Gentleman commences with "Rules and observations respecting the form and strength of beams of wood and iron for supporting weights, working engines, &c.

"If the materials of which different beams are made, be equally good, the comparative strength under any regular form may easily be investigated. But we find by experiment that the same kind of wood, and of the same form and dimensions, will break with very different weights; or, one piece is much stronger than another, not only cut out of the same tree, but out of the same rod; or, a piece of a given length, planed equally thick, and cut in two or three pieces, these pieces will be broken with different weights. Iron also varies in strength, and not only from different furnaces, but from the same furnace, and the same melting; but this seems to be owing to some imperfection in the casting, and in general iron is much more uniform than wood. The resistance which any beam or of wood or iron affords, will be as the sum of the products of all the fibres, between the top and bottom, multiplied by their respective distances from the top. For if $a =$ length, $b =$ breadth and $z =$ depth, we shall have $z \times z$, and divided by $\frac{a}{2}$; the fluent of $zz = \frac{z^2}{z}$; hence, $\frac{bz^2}{2} =$ the whole resistance, which when the weight is suspended from the middle of the beam, must be divided by half the length, or by $\frac{a}{2}$, which will be equal to $\frac{bz^2}{a}$; which expresses the strength of the beam. From which we have the following

Rule.—"*Multiply the breadth in inches by the square of the depth in inches, and divide that product by the length in inches, the quotient is a fraction, or whole number, &c. which expresses the comparative strength of the beam.*

"The dimensions may be taken in feet, or the breadth and depth in inches, and the length in feet, but to compare one piece with another they must all be taken in the same manner. From a great number of experiments which I have made on the strength of wood, and that on pieces of various lengths and breadths, &c. I found that the worst or weakest piece of dry heart of oak, 1 inch square and 1 foot long, did bear 660 pounds, though much bended, and two pounds more broke it. The strongest piece I have tried of the same dimensions, broke with 974 pounds.

"The worst piece of deal I have tried, bore 460 pounds, but broke with 4 more. The best piece bore 690 pounds, but broke with a little more. These pieces were 1 inch square, and 1 foot long.

Example 1.—"Given a piece of oak 6 inches square, and 8 feet in length, to find what weight suspended from the middle will break it.

Solution.—"In the worst piece of oak 1 inch square, and 12 inches long, the strength is 1 squared, viz. the depth squared and multiplied by the breadth, and divided by the length, which is $\frac{1}{12}$:

In the given piece we have 6 the depth squared equal 36, which multiplied by the breadth (6) gives 216, which divided by the length 96, gives $\frac{216}{96}$, or, $\frac{9}{4}$: hence as $\frac{1}{12}$ is to 660 pounds, so is $\frac{9}{4}$ to 17820 pounds.

"From the above, we may compute the following weights, which placed opposite to the fraction or whole number, which is obtained by the rule before given, and the dimensions taken in inches; in the second column, in feet; in the third, the breadth and depth in inches, and the length in feet.

The square of the depth multiplied by the breadth and divided by the length	Weight in pounds which will nearly break it, 1st	Dimensions taken in feet, 2d	Weight in pounds.	Breadth and depth in inches.	Length in Feet, 3d
$\frac{1}{12}$	660	$\frac{1}{1778}$	660	1	660
$\frac{1}{10}$	792	$\frac{1}{80}$	14256	$\frac{4}{3}$	880
$\frac{1}{8}$	990	$\frac{1}{60}$	19008	[illegible]	1650
$\frac{1}{6}$	1320	$\frac{1}{40}$	28512	3	1980
$\frac{1}{4}$	1980	$\frac{1}{30}$	38016	4	2640
$\frac{1}{2}$	3960	$\frac{1}{20}$	5702	5	3300
1	7920	$\frac{1}{10}$	114048	6	3960
2	15940	1	1140480	8	5280
3	23760			0	6600
4	31680				

 "*Example*

"*Example.*—Given, the length of an oak beam 16 feet, breadth 15 inches, and depth 18 inches, required its strength; or, the weight which suspended from the middle, will nearly break it."

"1. Let the dimensions be taken in inches, and we have $\frac{18^2 \times 15}{192} = 25\cdot3125$; the from the first column of the table we say, as $\frac{1}{8}$ is to 660 pounds so is 25·3125 to 200475 pounds the answer."

"2 Let the dimensions be taken in feet, and we have $\frac{1\cdot5 \times 1\cdot5 \times 1\cdot25}{16} = \cdot1757 = \frac{45}{256}$; and from the second column in the table we may say, as $\frac{1}{1728}$ is to 660 pounds, so is $\frac{45}{256}$ to 200475.

"3. The breadth and depth in inches, and the length in feet, and we shall have the breadth multiplied by the square of the depth, equal 4860, which divided by 16, gives $\frac{1215}{4}$ or 303 75, and as in the third column, as 1 is to 660 pounds, so is 303·75 to 200475 pounds, the answer."

"A beam of the above dimensions is commonly used for working a steam engine, the cylinder of which is from 20 to 24 inches diameter, suppose 22 inches, then the greatest pressure that can possibly act upon the beam will not exceed 10000 pounds; hence, the beam would require above 20 times the force of the engine to break it, nevertheless if it was much weaker, the engine might bend it, and in time break it.

"Suppose we take the above beam for a standard, or conclude that every beam ought to be able to bear 20 times as much as it is employed to do. Then what must be the dimensions of a beam 20 feet long, to work a cylinder 36 inches diameter.

"*Solution.*—The weight suspended from the ends of the beam will be as the squares of the diameters of the cylinders, viz. as 22 squared, and 36 squared, or as 484 to 1296, the last divided by the first, gives 2·6777, or $\frac{324}{121}$; so that the strength of the new beam must be 2·6777 times as great as the other. The strength of the first, when the breadth and depth are taken in inches, and the length in feet is expressed by $\frac{1215}{4}$ which multiplied by $\frac{324}{121}$, gives $\frac{393660}{484}$; equal 813·34 for the strength. If no regard is paid to the ratio of the breadth and depth, the problem is simply answered by assuming the breadth what we please, suppose 18 inches, and z = the depth we shall have $\frac{18\,z^2}{20} = 813\cdot34$; and z^2 will equal $\frac{813\cdot34 \times 20}{18} = 903\cdot71$; the square root of which is $= z$, or the depth $= 30$ inches nearly.

Otherwise, let the depth be taken at 27 inches and let b = breadth, then our theorem will become $\frac{b \times 27^2}{20} = 813\cdot34$; or, $b = \frac{813\cdot34 \times 20}{729} =$ 22 31 inches.

IN WORDS.

"*Rule.—Multiply the expression for the strength, by the length of the beam in feet, and divide that by the square of the depth in inches, the quotient will be the breadth in inches.*

"N. B. Though the above two beams are equally strong, yet the second contains about $8\frac{1}{4}$ feet more wood than the first.

PROBLEM 2.

"Let it be required to make a beam equally strong with the last, and of the same length, but that the ratio of the breadth to the depth be as 2 to 3, or in any other proportion? Let a = length in feet, b = breadth, z = depth, and $s = 813\cdot34$, the expression for the strength.

"Then will $\frac{b\,z^2}{a} = 813\cdot34$; and $z^2 = \frac{813\cdot34 \times a}{b}$ also by the problem, as $2 : 3 :: b : z$; hence, $2\,z = 3\,b$; and $z = \frac{3\,b}{2}$, which squared, gives, $z^2 = \frac{9\,b^2}{4}$; also $\frac{s\,a}{b} = z^2 = \frac{9\,b^2}{4}$; from whence we get $b^3 = \frac{4\,s\,a}{9} = \frac{4 \times 813\cdot34 \times 20}{9} = 7229\cdot7$ the cube root of which, is 19·337, the breadth in inches, and as $2 : 3 :: 19\cdot337 : 29\cdot005$, the depth in inches.

"If m is to n as the breadth to the depth, we shall have the following general theorem, viz. $b^3 = \frac{m^2\,s\,a}{n^2}$.

PROBLEM 3.

"Required to make a beam 24 feet long, to work a cylinder 24 inches diameter, and that the breadth be to the depth, as 3 to 7.

"To find an expression for the strength of the beam, we may say from the last problem, as 484, the square of the diameter of the cylinder, is to the expression for the strength of its beam, so is 576, the square of the diameter of the present cylinder, to number which will express its strength, viz. as 484 $\frac{1215}{4}$ :: 576 : 361·487, the number required.

"But when the length is taken in feet, and the breadth and depth in inches, we know that an oak beam, which will just break with 660 pounds, has its strength expressed by 1, and if we wish to have a beam which will bear 20 times as much as it is intended to load it with, we may take $\frac{1}{20}$ part th

the load, viz. $\frac{1}{20}$ of 660, or 33, and say, as 33 : 1 :: twice the area of the intended cylinder multiplied by 14, to the strength of the beam, in this case, as 33 : 1 :: 12672 : 384, the strength. But this is much more than the real load of a common 2 feet cylinder, if it should amount to even 10 pounds per inch, the whole would be only 8640 pounds, and as 33 : 1 :: 8640 : 261·8 the strength; let a beam be constructed by both expressions, viz by 384 and 262. In the first case, by the general theorem, $b^3 = \frac{m^2 s a}{n}$; in the problem, $m = 3$, and $n = 7$, also $a = 44$, and $s = 384$, therefore $\frac{9 \times 384 \times 24}{49} = b^3 = 1692{\cdot}7$, the cube root of which is the breadth $= 11{\cdot}918$ inches; and as 3 : 7 :: 11·918 : 27·808 inches, the depth. I have known a beam of deal of this size, used for a 2 feet cylinder, but in a few years it was much bended, though there was no danger of its breaking.

"Secondly, when the strength is expressed by 262, we have every thing the same as before, except $s = 262$, therefore $\frac{9 \times 262 \times 24}{49} = b^3 = 1155$, and the breadth $= 10{\cdot}492$ inches, and as 3 : 7 :: 10·492 : 24·48 inches, the depth.

"But suppose the engineer wishes it to support any greater weight, for instance, 25 times its common load, he may divide 660 by 25, and the quotient will be 26·4; then as 26·4 : 1 :: 8640 : 327·2 the expression for the strength, and $\frac{327{\cdot}2 \times 24 \times 9}{49} = b^3 = 1442{\cdot}351$; its cube root is $11{\cdot}29 = b$. And as 3 : 7 :: 11·29 : 26·34, the depth.

"By the above process, we find the strength of a beam to work a 12 inch cylinder expressed by 96, from which we have the following

"*Rule.—Square the diameter of the cylinder in feet, and multiply the product by 96; the last product will express the strength.*

N. B. The depth and breadth are taken in inches, and the length in feet, which I think is the most convenient in general. The length of the beam will make no difference, for the dimensions will turn out so as to make it equally strong of any length, for example.

PROBLEM 4.

"Required a beam 16 feet long, to work a cylinder of 30 inches diameter, and that the breadth be to the depth, as 3 to 5.

Solution.—"2·5 feet squared, is 6·25; which by the rule, multiplied by 96, gives 600 for the strength.

"Then by the theorem, $b^3 = \frac{m^2 sa}{n^2}$; $m^2 = 9$; $n^2 = 25$; $s = 600$; $a = 16$, therefore $\frac{9 \times 600 \times 16}{25} = b^3 = 3456$; the cube root of which, is 15·119 inches, and as 3 is to 5, so is the breadth 15·119 to the depth 25·198 inches.

"Let it be required to make a beam for the same cylinder of 24 feet, then will $\frac{9 \times 600 \times 24}{25} = b^3 =$ the breadth $= 5184$, the cube root of which, is 17·307, from which we find the depth 28·845 inches. This is equally strong with the first, but *contains much more wood.*

PROBLEM 5.

"Required a deal beam 16 feet long, to work a cylinder of 1 foot diameter, the breadth to the depth, as 3 to 5.

Solution.—"If we take the pressure at 14 pounds per inch, the weight upon the centre will be about 3168 pounds, also the worst piece of fir, one inch square, and one foot long, bore 460 pounds, and broke with 7 pounds more; hence, if we take $\frac{1}{20}$ part of 460, viz. 23 pounds, and say, as 23 : 1 (the expression for its strength,) so is 3168: 137·7 the strength. Then from the theorem we multiply the length, the strength, and the square of the ratio of the breadth together, and divide by the square of the ratio of the depth, viz. $\frac{16 \times 137{\cdot}7 \times 9}{25}$ is 973·152, the cube root of which, is 9·9 inches for the breadth, then as 3 : 5 :: 9·9 : 16·5 inches, the depth.

"Hence, if the square of the diameter of any cylinder in feet, is multiplied by 138, for the strength of a deal beam, it will, without breaking, support more than 20 times as much weight as the engine can ever exert upon it.

Experiments on the strength of oak.

"These experiments have been made on pieces of one inch square, and one foot long, and from that size to 2 inches square, and five feet long, to mention all the trials would take up time and room to no great purpose. It may be sufficient to observe, that when the computations made on the different pieces, and applied to pieces 1 inch square, and 1 foot long, that the worst would bear 660 pounds, and the best not more than 974. From similar experiments on deal of the same dimensions, I found the worst which I used would just break with 460, and the strongest with 690 pounds.

"But in all the computations, I have taken the worst pieces to compute from, and at the same time have made them to bear 20 times as much as the load they have to support; not taking notice of their own weight, which would have made the process much more troublesome.

PROBLEM 6

"Required the length of a piece of oak one inch square, so that it may just break with its own weight.

Solution.—"Let $x =$ the length in feet, and one foot

foot in length weigh $\frac{4}{10}$ of a pound. Then as 1: $660 :: \frac{1}{x} : \frac{660}{x}$ the weight which will break it, but the bar only acts with half its own weight at the centre, therefore $\frac{4x}{10}$ the weight of the bar, must be equal to $\frac{660}{x} \times 2$; viz. $\frac{1320}{x} = \frac{4x}{10}$; or, $13200 = 4x^2$, and $x = \sqrt{3300} = 57{\cdot}44$ feet.

Experiments on the strength of cast iron.

"Of late cast iron has been used in various cases in place of stone or wood, as in bridges, engine beams, pillars, rail ways, or roads, &c. and is still likely to be more in use. The following experiments were given to me by Messrs. Reynolds, of Ketley, at the same time requesting me to make them as public as I could, for the advantage of others.

Experiments on the strength of cast iron, tried at Ketley, March, 1795.

N. B. The different bars were all cast at one time out of the same air furnace, and the iron was very soft so as to cut or file easily.

Experiment 1.—" Two bars of cast iron, one inch square, and exactly 3 feet long, were placed upon an horizontal bar so as to meet in a cap at the top, from which was suspended a scale; these bars made each an angle of 45° with the base plate, and of consequence at the top so as to form an angle of 90°, from this cap was suspended a weight of 7 tons, which was left for 16 hours, when the bars were a little bent, and but very little.

Experiment 2.—" Two more bars, of the same length and thickness, were placed in a similar manner, making an angle of 22½° with the base plate; these bore 4 tons upon the scale; a little more weight broke one of them, which was observed to be a little crooked when first put up. In this case the pressure would be as the sines of the angles of elevation, viz. as 3826 to 7071; and as 3826 : 4 tons :: 7071 : 7·6 tons, that is if the second bars broke with 4 tons, the first ought to have taken 7·6 tons to break them, and as they were not broken it is likely that would, if tried, have been the case.

Experiment 3.—" Another bar was placed horizontally upon two supporters, exactly 3 feet distant, it bore 6 cwt. 3 qrs. but broke when a little more was added.

Experiment 4.—" The same experiment repeated, with the same result.

Experiment 5.—" The bearings were 2 feet 6 inches apart, the bar bore 9 cwt, and broke. This was perceptably bent with 1 cwt. but bore two safely. Three more experiments were tried the next day with the prisms 3 feet distant; the average result was 6 cwt, 2 qrs. 7⅓ pounds.

Experiments tried at Colebrookdale, on curved bars or ribs of cast iron, April, 1795.

" Rib 29 feet 6 inches span, and 11 inches high in the centre, it supported 99 cwt. 1 qr. 14 lbs. it sunk in the middle 3¼, and rose again ¼ when the weight was removed. The same rib was afterwards tried without abutments, and broke with 55 cwt. 0 qrs. 14 pounds.

Experiment 6.—" Rib 29 feet 3 inches in span; a segment of a circle 3 feet high in the centre, it supported 100 cwt. 1 qr. 14 lbs and sunk $1\frac{3}{16}$ in the middle. The same rib was afterwards tried without abutments, and broke with 64 cwt. 1 qr. 14 pounds.

N. B. The thickness of these ribs is not mentioned, but the experiments shew that they are much stronger with abutments; as little more than half the weight which they support, breaks them when the abutments are removed.

" The following experiments on cast iron, I made at Messrs. Aydon and Elwell's foundry, at Wakefield, the iron came from their furnace at Shelf, near Bradford, and was cast from the air furnace; the bars one inch square, and the props exactly one yard distant, one yard in length weighs exactly 9 pounds, or one was about half an ounce less, and another a very little more; they all bended about one inch before they broke.

1. The first bar broke with........963 pounds.
2. Bar broke with..............958 pounds.
3. Bar broke with..............994 pounds.
4. Bar made from the cupola, broke with.....................864 pounds.
5. Bar equally thick in the middle, but the ends formed into a parabola and weighed 6 lbs, 3 ozs. broke with....................874 pounds.

" Other experiments were made by giving the same quantity of iron a different form, (*see fig.* 11) The top and bottom of this beam were each 1 inch broad, and half an inch thick, till they joined at a and b, where they were one inch square; the piece c, d, in the middle from which the weight was suspended, increased the weight of this to 10¼ pounds. The length from prism to prism, viz. from prop to prop, was an exact yard; the depth in the middle from top to bottom, 4½ inches The first piece bore 29 cwt. 20 lbs, and broke with a little more. A second piece bore 23 cwt. 1 qr. but broke with another half cwt.

" A second form is represented in *fig.* 12, where the bar a c b is 1 inch broad, and $\frac{6}{10}$ inch deep, the bar a d b is also 1 inch broad, and $\frac{4}{10}$ inch thick, so that it contains no more iron than the straight bar, except the piece at c, from which the weight was suspended; the weight of these was 10 pounds each, the depth c, d, 4½ inches, but there was no connection betwixt the two, except at the ends were they were in one piece.

" Trial

piece at c, and the lower at the props.

"Trial 2. 48 cwt. 2 qrs. 7 lbs. broke this in the same manner as the other. A gentleman present wished to have the upper and lower part connected, as at the dotted lines; one was cast in this form, and broke with 31 cwt. 2 qrs. another bore above 40 cwt.

"Another beam of the same length and depth at the centre, but in the form of a parabola, and weighed 10 ½ pounds, the flat part of the beam was ¼ of an inch thick, and was surrounded by a moulding ½ of an inch thick, and on the outside 1 inch broad: first trial broke with 50 cwt. 3 qrs. 25 lbs. a second piece, or beam, broke with 44 cwt, 3 qrs. but on examining the fracture, it was full of pores at the gate, or place, where the metal entered the mould. *See fig.* 13.

"From the above experiments, it appears that cast iron is from 3½ to 4½ stronger than oak of the same dimensions, and from 5 to 6½ times stronger than deal.

"Iron is much more uniform in its strength than wood, yet it appears that there is some difference in different kinds of ore or iron stone; there is also a difference from the same furnace, perhaps owing to the degree of heat which it has, when poured into the mould. If we take iron upon an average to be 4 times as strong as oak, and 5½ as strong as deal, we may proceed to make comparison betwixt wood and iron, in respect of magnitude, weight, expence, &c.

"It is proved by the experiments, that the worst or rather weakest cast iron, 1 inch square, and 3 feet long, will break with about 730 pounds, and as ⅓ (viz. the breadth and square of the depth multiplied together, and divided by the length in feet) is to 730 pounds, so is ⅓ or 1 to 2190 pounds, the weight which would break a bar 1 inch square, and 1 foot long. But I have computed the beams of wood to bear 20 times as much as the intended load. Let the iron be made to support 6 times the weight, which I presume, from observation, will be sufficient to keep them from bending, or vibrating. But if the engineer thinks differently, he may make them of what strength he pleases by the following

"*Rule.—Divide* 2190 *by the number of times you wish to encrease its strength above the load, and say as the quotient is to* 1, *so is the load of your new beam to the number which expresses its strength.*

"For example, the load upon a 12 inch cylinder will be about 3168 pounds. One sixth part of 2190 will be 365, and 3168 divided by 365, quotes 8·6; which expresses the strength for cast iron.

PROBLEM 11.

"Let it be required to make a cast iron beam for a 12 inch cylinder, so that the breadth may be to the depth as 1 to 6, and the length 14 feet. Here we have $a = 14$; $m = 1$; $n = 6$; $s = 8{\cdot}6$; then $b^3 = \frac{m^2 sa}{n^2} = \frac{120{\cdot}4}{36} = 3{\cdot}344$, and $b = 1{\cdot}4954$ inches, which multiplied by 6, gives 8·9724, the depth.

"*On the strength of beams, or poles of wood or iron, when used in the form of triangles, to support weights, load waggons, raise stones upon buildings, &c.*

"*Fig.* 14.—Let BSC, be the triangle, then as the sine of the angle which B S makes with the horizon, is to the radius, so is the whole weight, suspended from the top S, to the pressure against S B and S C, for if they stand in the same position, they will support equal parts of the weight.

"Those who have not tables of natural sines by them, may proportion by saying, as S D the altitude of the pin, which supports the weight, is to the length of a pole or leg of the triangle, so is the weight suspended to double the pressure against one pole, that is when the triangle consists of two poles. If there be three poles, as for loading carriages, &c. we may say, as the perpendicular altitude of the pin is to the length of one pole, so is one third of the weight to the pressure against one pole. According to Messrs. Reynold's experiments, we easily infer, that a bar of cast iron one inch square, and one foot long, will bear a pressure against the ends of about 15 tons, and it appears from other experiments, that deal, alder, and other soft wood of the same dimensions, will bear about 2·3 tons; but suppose we call it only two tons.

"From which we get the following proportions.

'For iron. As 1 : 15 :: the expression for its strength, to the weight which it will bear.

"For wood. As 1 : 2 :: the expression for its strength to its load.

PROBLEM XX.

"*Examples.*—Given, two pieces of cast iron, two inches square, and 16 feet long, making an angle with the horizon of 60° each, what weight will they support?

"*Solution.*—The expression for the strength is the cube of a side in inches, divided by the length in feet, viz. $\frac{8}{16} = \frac{1}{2}$, and the natural sine of 60°, when the radius is 1, is .8660254, for the weight which the bar can bear against its end, say, as 1 : 15 :: ½ : 7½ tons. Next, as the length of the bar is to its perpendicular altitude, viz. as 1 : 8660254 :: 7·5 : 6·49519, which doubled, is 12·99 tons, for the whole load?

PROBLEM XXI.

"Suppose the same bars make each an angle of 30° with the horizon, what weight will they bear?

"*Solution.*—The strength as before is ½; and the pressure which they can support is 7½ tons, the sine of 30° is ·5, and as 1 : ·5 :: 7·5 : 3·75 tons for each bar, and the whole load is twice as much, or 7½: hence, it appears that the less the angle which they

make with the horizon, the less weight will they support.

"N. B. In round and square props, poles, &c. of equal length and weight, the round will be stronger nearly in the ratio of 31 to 29. But if the lengths are equal, and the diameter of the round, equal to a side of the square pole, the strength of the round pole will be to that of the square one as 21 to 29, nearly.

PROBLEM 22.

"Three poles 4 inches diameter and 10 feet long, make each an angle of 60° with the horizon, what load may be suspended from them?

"*Solution.* $\frac{4 \times 4 \times 4}{10} = 6{\cdot}4$ for the strength, then as $1 : 2 :: 6{\cdot}4 : 12{\cdot}8$ tons, the strength of one pole. And as radius is sine of 60° so is 12·8 to 11 tons, the weight which will produce a pressure of 12·8 against one pole, the whole three will therefore support 33 tons.

PROBLEM 23.

"Required a triangle with 2 legs 20 feet high, and making an angle of 70° with the horizon, what must be their diameter to support 3 tons, that is each $1\frac{1}{2}$.

"*Solution.*—As the sine of 70° ·9396926 : radius $1 :: 1\frac{1}{2}$ half the weight : 1·5963, the pressure upon one pole. And $\frac{x^3}{20} = 1{\cdot}5963$, or $x^3 = 1{\cdot}5963 \times 20 = 31{\cdot}926$; $x = (31{\cdot}926)^{\frac{1}{3}} = 3{\cdot}17$ inches, the diameter of a pole.

PROBLEM 24.

"Required, a triangle with 3 legs, each making an angle of 60° with the horizon, and 12 feet long, to support scales for weighing of 4 tons, viz. the whole load will be 8 tons.

"*Solution.*—First, as the sine of 60° ·866 &c. : radius $1 :: 2{\cdot}666$, one third of the weight, to 3·077 tons, the pressure on one pole. Then $\frac{x^3}{12} = 3{\cdot}077$; and $x^3 = 36{\cdot}924$; hence, $x = (36{\cdot}924)^{\frac{1}{3}} = 3{\cdot}298$ inches, the diameter of a pole.

"N. B. In the above problems, the legs will do no more than bear the weight, but if we want a triangle to support eight tons, we ought by all means to make it strong enough to bear 3 times as much, and then we should say, as $\cdot 866$ &c. $: 1 :: 8 : 9{\cdot}23$ tons, and x^3 will equal $9{\cdot}23 \times 12 = 110{\cdot}76$; and $x = (110{\cdot}76)^{\frac{1}{3}} = 4{\cdot}8016$ inches.

"If wood, metal, &c. intended for bows, springs, &c. be formed of the above process, they will be equally strong from end to end, but if one side is to be flat and equally broad through the whole length; then the other side is formed into a parabola, by the rule given for engine beams.

"When shafts are placed in an upright position, they are only in danger of being broken by the twist, between the wheel which drives them, and the resistance they have to overcome. A cast iron bar 1 inch square, fixed at one end, and 631 pounds suspended by a wheel of 2 feet diameter, fixed on the other end, will break by the twist. The strength of square bars in resisting the twist, is as the cube of a side. In round bars or spindles, as the cube of the diameter. Hence, if a bar of 1 inch square, requires 631 pounds to break it, one of 2 inches square, will require 8 times as much; and one of 3 inches 27 times, or 7037 pounds.

"*I have made experiments on some bars of the same size, and the power or force applied in the same manner, which have required 1008 pounds to break them by twisting, but have mentioned the worst I have tried, that I might not deceive.*

"It has been observed, that there is no weight or pressure to break these upright spindles besides the twist, yet it may be noticed, that weight on the top, the shaking of the machinery, &c. tends to make them vibrate, on which account it may be well to make them something thicker at the middle than at the ends.

PROBLEM 25.

"If a shaft 3 inches square, will just bear the force acting upon it, how much must a side of the square be, when it is strong enough to bear 5 times as much?

"*Solution.*—The strength is here represented by the cube of $3 = 27$, which multiplied by 5, gives 135, the cube root of which, is 5·13 inches for the answer.

PROBLEM 26.

"*Fig.* 15.—A weight w, is suspended from E the arm of a crane A B C D E, what is the pressure against the end of the spur D B?

"*Solution.* $\frac{CE \times W}{CD} =$ the pressure at D, in the direction D G; but the pressure at D, in the direction D B, will be as D G to D B; that is, as $DG : DB :: \frac{CE \times W}{CD} : \frac{DB \times EC \times W}{BC \times CD}$. Also, the pressure against the upright post A C at B, in the direction G B, will be as B C : C D. viz. as $BC : CD :: \frac{CE \times W}{CD} : \frac{CD \times CE \times W}{BC \times CD} = \frac{EC \times W}{BC}$.

EXAMPLE I.

"Given, E C = 16 feet, B C or D G, = 7 feet, D C = 7 feet, W = 3 tons, D B = 9·9: then from the above, we have $\frac{DB \times EC \times W}{DG \times DC} = \frac{9{\cdot}9 \times 16 \times 3}{7 \times 7} = \frac{475{\cdot}2}{49} = 9{\cdot}6979$ tons, for the pressure against the spur D B.

"For the perpendicular pressure against the upright axle A C, we have $\frac{EC \times W}{BC} = \frac{16 \times 3}{7} = 6{\cdot}8571$

$=6.8571$ tons, the force tending to break the said piece at B.

EXAMPLE 2.

Given E C $= 12$
B C $= 6$
D C $= 6.7$
D B $= 9$
W $= 4$

"Required the pressure on the spur, and the horizontal pressure against the upright.

"1. $\frac{DB \times EC \times W}{DG \times DC} = \frac{9 \times 12 \times 4}{6 \times 6.7} = 10.74$, the pressure against the end of the spur. The pressure against the post, is $\frac{EC \times W}{BC} = \frac{12 \times 4}{6} = 8$. In this example, let A C and C E, be oak beams, each 10 inches square, and the spur D B, be six inches square. The strength of E C is $\frac{1000}{10.6}$, or $94\frac{1}{3}$: which, multiplied by 660, gives 31132 pounds, which, suspended at E, would break the beam C E at D. The length of the upright A C, is 12 feet, and has its strength expressed by $\frac{1000}{12}$, which multiplied by 660, produces 55000 pounds, the weight which would break it at B. But $\frac{31132 \times 12}{6} = 62264$, the pressure at B, which is 7264 pounds more than the beam A C can support. The strength of the spur B D is $\frac{6 \times 6 \times 6}{9} = 24$, which multiplied by 2, gives 48 tons for the strength, or 107520 pounds. But $\frac{DB \times EC \times W}{DG \times DC} = \frac{9 \times 12 \times 31132}{6 \times 6.7} = \frac{3362256}{40.2} = 83638$ pounds, which is 23882 pounds less than the force requisite to break the spur. From the above, it appears that the upright A C is the weakest part: but from the principles already explained, the ingenious mechanic will easily proportion the parts so as to be equally strong. I will add one example. In the above crane the horizontal beam bears 31132 pounds, the length of the spur and upright being given, what must be their dimensions, that is, how much square, to be equally strong as the above horizontal beam?

"First for the spur. Let $z =$ side of the square, then $\frac{z^3}{9} \times 4480 = 31132$ pounds, or $z^3 = \frac{9 \times 31132}{4480} = 62.542$; and $z = 62.542^{\frac{1}{3}} = 3.9694$ inches.

Second.—The strength of the upright is expressed by $\frac{z^3 \times 660}{12}$, which must be equal to .62264, hence $z^3 = \frac{62264 \times 12}{660} = 1132.006$; its cube root is $10.422 = z$, the side of the square post.

Let it be required to make a crane of cast iron to bear 4 cwt. but that it may be perfectly safe, let it be calculated for 10 cwt. and let A C $=$ C E $=$ 3 feet, also B C $=$ C D $= 1\frac{1}{2}$ foot.

Solution.—Let the thickness of the iron be half an inch, and put $z =$ depth of C E. Then as $1 : 2190 :: \frac{z^2 \times \frac{1}{2}}{3} : 1120$, from which we find $z^2 = \frac{1120}{365} = 3.0685$; the square root of which, is the depth $= 1.75$ inches. The pressure upon the spur at D, in the direction D G $= 1120$ pounds; the length of the spur is 2.12 feet, and as D G (1.5) : D B (2.12) :: 1120 : 1583, for the pressure in the direction D B. As a bar one inch square, and one foot long, will bear 15 tons, or 33600 pounds, we say as $1 : 33600 :: \frac{z^3}{2.12} : 1583$, from which we find z the side of the prop or spur $= .46385$ of an inch square. Next, for the upright, we have $\frac{CE \times W}{BC}$, or, $\frac{560 \times 3}{1.5} = 1120$ pounds, the pressure against B, then as $1 : 2190 :: \frac{x^2}{3 \times 2}$ the square of the breadth to 1120 pounds, the same as C E, as they are of the same length, and the breadth will be the same, that is 1.75 inches.

We shall now present to the attention of our readers, a few interesting problems, collected from various sources.

In the 6th number of that valuable publication, the "*Gentleman's Mathematical Companion*," we find the following question proposed by the truly ingenious Mr. Joseph Edwards, private teacher of the mathematics, at Hoxton, and most elegantly resolved by him, in the succeeding year.

PROBLEM.

"Let S denote the strength of a parellolopipedic beam of timber, at any given place, found according to the common principles. Required the strength at the same place, supposing the expansion and contraction of the fibres, when at the greatest, to have a given ratio."

SOLUTION.

"Let the parallelogram A B C D, (*Fig. 16.*) represent the given beam supported at the middle of B C, by the fulcrum F, and strained by two equal weights suspended to its ends; and parallel to which let E F be a section.

In the investigation of the lateral strength of timber, upon the common principles, the common fulcrum of the bended levers, B F E, C F E, is supposed to be in the surface of the beam at F, and consequently that all the longitudinal fibres resist (in various degrees) the tendency of the force of the weights to overcome the cohesion at the section, in the direction of their lengths but when the fibres are susceptible both of contraction by pressure, and expansion

expansion by tension, it is evident, that the beam will, as soon as it is submitted to the action of sufficient weights, turn (until it breaks) about that point (O) in E F, which divides the expanded from the contracted fibres, and of the latter, an equal number in each part F A, F D, may be imagined to press upon each other at O F, and form a common finite base, upon which the said levers are supported when they strain the fibres between O and E. Now from hence, it is evident, that the magnitude of O F depends upon the ratio e e to F F, if these lines represent the increment and decrement of an expanded and contracted fibre, respectively: which being given, that of E O : O F is also given by sim. $\triangle$ s; and E F being given, E O, O F, are each given."

"Again, draw J O K ∥ B C, then (by prop. 57 Emerson's Mech.) the strength of the beam A I O K D, of which the depth is E O, and fulcrum O, is as $\frac{E o^2}{3}$ when O K is given, and the breaking tension of a fibre at O, $=1$; also $\frac{Eo}{2} =$ sum of all the tensions at EO, therefore it is evident that all the fibres in the beam, AK would be broke by a force at K, which is as $\frac{E o^2}{3}$ if the arm OF, of the double lever K O E, K O F, were not prevented from turning about the fulcrum O, by the resistance of those fibres at O F, which belong to the part I F of the beam, which resistance $= \frac{E o^2}{2 E o + 2 F E}$ as appears from what has been quoted above, and the property of the lever. Moreover, because the resistance at O F is equal to the sum of all the tensions at E O $\frac{C o^2}{2 E o + 2 F O}$: $\frac{E o^2}{3}$ :: $\frac{E o}{2}$: $\frac{E o}{3} \times (E O + O F)$, the greatest weight that the given beam will support, or the least that will break it. But $\frac{E F^2}{3}$ is as the strength of the beam, according to Emerson's principles; therefore $\frac{E F^2}{3}$: $\frac{E O}{3} \times$ E F :: E F : E O :: S : S $\times \frac{E O}{E F}$ the strength of the given beam as required. Hence it follows, if the beam be soft and elastic (as fir, yew, &c.) that it will acquire additional strength by cutting a piece out of the under part on each side of O F, and subtituting a similar one of a firmer texture in its stead."

In the 14th number of the *Mathematical Companion*, we find the following interesting question, proposed by Mr. John Surtees, of Houghton Le Spring, in the county of Durham.

"A beam of a given length, having its perpendicular section every where a plane triangle vertex upwards, projects horizontally from a wall. Compare its strength, when whole, to support a weight at its end, with the strength of the remaining piece, after $\frac{1}{4}$ of the section from the vertex is cut away parallel to the horizon; also with the strength of the remaining piece, after $\frac{2}{9}$, $\frac{3}{4}$, $\frac{4}{5}$, &c. is cut away, the weight of the beam itself not being considered."

"*Note*—In *Emerson's Mechanics*, page 114, it is asserted, that, when $\frac{1}{9}$ is cut away, the remaining piece is stronger than when whole, which is a paradox in mechanics. But I presume that a true solution to the above will prove that to be a mistake."

The correctness of this assertion, the ingenious proposer fully demonstrated (on the supposition that the beam was destitute of weight), in the 15th number of the same publication: to which the reader is referred for a very excellent solution of the foregoing question.

The writer of this article has received the following very elegant and masterly solution of this interesting problem, from Mr. William Watts, of Plymouth; a Gentleman whose eminent scientific attainments, are surpassed only by his ingenuous modesty.

"Let the triangle A B C (*Fig.* 17,) represent a perpendicular section of a beam, supposed to project horizontally from a wall, and let a weight W be applied at the other extremity to break it; also let A B C represent the section when the fracture takes place, the fulcrum being at D.

"Put C D$=$a, D B$=$b, D E$=$v, and E F$=$y. Let L also denote the length, and W the weight of the whole beam, and let l and w be considered as the length and weight of any trapezoid or horizontal section of the beam. Then by sim. triangles C D (a): BD (b):: CE (a—v) : EF (y)$= \frac{b}{a}$ (a—v), and by substituting this value of y in the known formula $\frac{y v^2 \dot{v}}{a}$ it will become $\frac{b}{a^2} (a v^2 \dot{v} - v^3 \dot{v})$ the fluxion of the strength of the beam: and by integrating each term, we shall have $\frac{b v^3}{3 a} - \frac{b v^4}{4 a^2} =$ the strength of the trapezoid B D E F, which expression when v$=$a becomes $\frac{1}{12}$ b a^2, the direct lateral strength of the entire beam.

These two strengths are to each other in the ratio of $\frac{1}{12}$ b a^2 ; $\frac{b v^3}{3 a} - \frac{b v^4}{4 a^2}$, or of 1 : $\frac{4 v^3}{a^3} - \frac{3 v^4}{a^4}$. (I).

"This ratio expresses only the relation existing between the strengths or efforts that tend to preserve the adhesion of the fibres. If, therefore, we would take into consideration the efforts that tend to destroy their adhesion, these efforts being in the inverse ratio of the strengths, will be found to vary both as to the weights of the respective beams, and the distance at which those weights act; therefore by incorporating

corporating the direct and inverse ratios, we readily find that the strengths are to each other in the ratio of $1 : \left(\frac{4\ v^3}{a^3} - \frac{3\ v^4}{a^4}\right) . \left(\frac{L\ W}{l\ w}\right)$ .... (11)

or of $1 : \left(\frac{4\ v^3}{a^3} - \frac{3\ v^4}{a^4}\right) . \left(\frac{W}{w}\right)$ ....(111)

when the lengths are the same.

"*Ex.* I. If $v = \frac{8}{9}$ a, then by the first form, the ratio for the direct strengths becomes $1 : \frac{4 \times 512}{729} - \frac{3 \times 4096}{6561}$, or as 2187 to 2048.

"*Example* 2.—If $v = \frac{7}{9}$ a, then the ratio of the direct strength (I) becomes, $= 1 : \frac{4 \times 343}{729} - \frac{3 \times 2401}{6561}$, or as 2187 to 1715."

"*Example* 3.—If $v = \frac{6}{9}$a, then by form (1), the ratio of the direct strengths becomes $= 1 : \frac{4 \times 216}{729} - \frac{3 \times 1296}{6561}$, or as 2187 to 1296."

"*Example* 4.—If $v = \frac{5}{9}$a, then by form (I) the ratio of the direct strengths becomes $= 1 : \frac{4 \times 125}{792} - \frac{3 \times 625}{6561}$, or as 2187 to 875."

"If we continue the examples by supposing $v = \frac{4}{9}$a, $\frac{3}{9}$a, &c. &c. we shall obtain a series of results the whole of which, with the preceding, are exhibited in the following table, where the several ratios are arranged in their proper order.

2187 to	2048	when 1 ninth is cut away.	
	1715	......2 ninths......	ditto
	1296	......3	ditto
	875	......4	ditto
	512	......5	ditto
	243	......6	ditto
	80	......7	ditto
	11	......8	ditto
	0	......9	ditto

"*Remark.*—It appears by the preceding solution, that the whole triangular beam is stronger than any remaining trapezoid whatever, after any triangular prism, similar to the given beam, is cut off from the top parallel to the horizon, and that Emerson was mistaken (at least in theory) in asserting that when $\frac{1}{9}$ of the altitude of the triangular prism is cut away; the remaining piece is stronger than when whole. But it should not be forgotten that the entire beam, being in the form of a triangular prism, and having a sharp edge at the vertex, is deemed by practical men, much more liable to spring than it would be if the upper edge were cut off parallel to the base of the prism; and it is probable that this circumstance may more than compensate for the loss of strength, occasioned by $\frac{1}{9}$ of the altitude of the beam being cut off from the top; but this I presume can only be determined by suitable experiment.

On comparing this solution with the one given by the proposer in the Mathematical Companion they will be seen to present the same results; from which circumstance it is evident that theory contradicts the assertion of Emerson, and all that remains now, is to institute a series of experiments, in order to ascertain the conclusion which may be deduced from them.

The writer has already commenced some experiments on the subject, which will most probably be communicated to the public in some form or other at a future day. As his sole object, however, in mentioning this, is to excite an emulation in others to undertake the task, it will be no mortification to him to be deprived of the honour of being the first, who shall either confirm or invalidate the assertion of Emerson, by correct experiments.

Although the preceding solution as well as that of Mr Surtees', have been conducted on the supposition, that the beam is devoid of weight, yet, even on this principle, Emerson's assertion will be found altogether erroneous.

In the mathematical department of the "*Enquirer*," is the following problem, an answer to which has not yet been published; though we shall now attempt it in the annexed solution.

PROBLEM.

"Two prismatic beams of equal length, whose sections are respectively a triangle and a trapezoid, the latter being cut from a triangular beam similar to the former, have their ends fixed in an upright wall, with their bases downwards; putting S, s, for the strengths of the beams G, g, for the distance of their centres of gravity from their bases, we shall have S : s :: G : g; required the investigation.

Solution.—Let A B C D, E F G H K, (*Figure* 18) be two beams of equal lengths and of the same materials, fixed in horizontal positions in a vertical wall; and let the latter be a prism cut off from a triangular beam which is equal and similar to D B C.

Put A = area of the section D B C; G = distance of its centre of gravity from the base B C; L = its length; W = its weight, and S its strength; and let a, g, l, w and s represent corresponding particulars in the other beam. Then it is well known that $S : s :: \frac{A.G}{L.W} : \frac{a.g}{l.w} :: A.\ G.\ l.\ w : a.\ g.\ L.\ W$ $:: A.\ G\ w : a.\ g.\ W$; and supposing we consider for example; that the trapezoid represents $\frac{80}{81}$ of the triangle D B C, (as Emerson has done, *vide* the foregoing question), we shall have $a = \frac{80\ A}{81}$ and $w = \frac{80\ W}{81}$, hence $S : s :: \frac{80\ A.\ G.\ W}{81} : \frac{80\ A.\ g.\ W}{81}$

:: 80 G : 80 g :: G : g ; as is required to be demonstrated.

This solution confirms the assertion made in the preceding problem; for as S and s, denote the respective strengths of the triangular and trapezoidal prisms, and these strengths bear an invariable ratio to G and g, (as has been just demonstrated), and knowing from the common properties of the centre of gravity in the beams that G is greater than g, we may be considered as correct when we assert that the strength of the former beam is greater than that of the latter, and this too, without any limit or regard to the size of the small triangular prism, supposed to be cut off from the whole triangular prism, in order to form the trapezoidal beam EFGHKHK.

To determine the position of the two posts AD and BE supporting the beam A B, so that the beam may rest in equilibrio.

Solution.—Through the centre of gravity G of the beam, (*Fig.* 19) draw C G perpendicular to the horizon; from any point C in which draw C A D, C B E, through the extremities of the beam; then A D and B E, will be the positions of the two posts or props required, so as AB may be sustained in equilibrio; because the three forces sustaining any body in such a state, must be all directed to the same point C.

Cor.—If G F be drawn parallel to CD; than the quantities of the three forces balancing the beam, will be proportioned to the three sides of the triangle C G F. viz. C G will be as the weight of the beam, C F as the thrust or pressure in B E, and F G, as the thrust or pressure in A D.

The strength of a beam A B, (*Figure* 20,) being given, it is required to find its strength, when a hole (a c), is cut out of the middle, and another equal hole (r n), in the side.

By the principles of mechanics, the strength of beams, the thicknesses of which are d b, d a, d c, will be as $d b^2$, $d a^2$, and $d c^2$. Now, as the strength of all the particles between b and d, is denoted by $d b^2$, and the strength of all the particles between a and d, is expressed by $a d^2$, consequently the strength of all the particles between b and a. (the point D being fixed), will be $d b^2 - d a^2$, add to the same, the strength between c and d, which is $c d^2$, and the strength of b a, and c d, when the strength of the hollow beam will be $d b^2 - d a^2 + c d^2$, but at the section r, the strength will be $f n^2$.

Whence, if n r = a c, the strength at b, to the strength at r, is as $bd^2 - d a^2 + cd^2$ to $(db - ca)^2$; that is, as $d b^2 - 2 d c \times c a - c a^2$ to $d b^2 - 2 d b \times c a + c a^2$. Therefore, if $d b^2$, be the strength of the whole beam $(2 d c + c a) \times c a$, will be the deficiency in strength of the hollow beam, when it breaks at b; and $(2 d b - c a) \times c a$, will be the defect of strength when it breaks at n or f, which is greater than the former. For the same reason the deficiency in strength required to break it at d, will be $(2 b d + a c) \times a c$.

Let A D, (*Figure* 21) be a beam in a horizontal position, supported at the end A by the upright piece A E: it is required to find the position of another piece B C of a given length, so as it may support A D with the greatest force possible.

Let B C denote the absolute strength of the beam B C; when agreably to the principles of the resolution of forces, C F will express that part of it which is employed in supporting A D: consequently by the property of the lever, A C × C F is to be a maximum.

But it is well known that the rectangle of two quantities forms a maximum, when those quantities are equal; therefore B C is in the best position for supporting A D, when A C = A B, or when the angle A B C, is equal to the angle A C B.

From these data, we learn that the cross bars of gates should not be placed diagonally, as they most commonly are; because the bar in that position counteracts, in a great measure, what it is intended to remedy.

We have now compleated what we proposed, in this third and last division of Carpentry; but we cannot permit ourselves to conclude it, without acknowledging how deeply we are indebted to the labours of different authors, for much important and valuable assistance throughout the whole of our enquiries. To the *Encyclopœdia's Britannica and Londinensis, Rees's Cyclopœdia, Emerson's, Gregory's, and Marratts Mechanics, Banks on the power of Machines, the different treatises on Carpentry,* and various other works, we acknowledge ourselves indebted in a particular manner, and would refer the enquiring student to the publications we have alluded to, for more particular information; and we can assure him that *they* will be found correct guides in general to a knowledge of those subjects which have been treated of in this part of our article.

JOINERY.

We have already defined to be the art of working in wood, or of fitting various pieces of timber to each other, for the purpose of ornamental appendages to certain parts of edifices, which are called by the French, *menuiserie*, "small work."

ENUMERATION OF THE MOST UESFUL JOINERS TOOLS.

Figure 30	represents	*the Jack Plane.*
—— 31	....	*Trying Plane.*
—— 34	....	*Smoothing Plane.*
—— 32 *and* 33	.....	*Plane Irons.*
—— 25	....	*Tenon Saw.*
—— 26	....	*Compass Saw.*
—— 27	....	*Keyhole Saw.*
—— 8	....	*Square.*
—— 23	....	*Bevel.*

Figure 17

Figure 17	....	*Guage.*
—— 4	....	*Mortice chissel.*
—— 14	....	*Gouge.*
—— 15	....	*Turn Screw.*
—— 29	....	*Plough.*
—— 35	....	*Moulding Plane.*
—— 37	....	*Pincers.*
—— 10	....	*Brad Awl.*
—— 2	....	*Stock and Bit.*
—— 20	....	*Side Hook.*
—— 28	....	*Work Bench.*
—— 38	....	*Rule.*

Besides these, Joiners make use of a variety of other tools, whose general forms are nearly similar to those exhibited in the Plate; and which consist of the *Long Plane*, *Jointer*, *Compass Plane*, *Fork-staff plane*, *Straight Block*, *Sinking Rebatting Planes*, *Skew mouthed Rebatting planes*, *Square mouthed Rebatting planes*, *Side Rebatting Planes*, *Bed Planes of various sizes*, *Sniper bill*, *Hollows and Rounds*, *Moulding Planes of various kinds*, (which would be endless to enumerate), *Centre Bit*, *Counter sink*, *Rimers*, *Taper Shell Bit*, *Drawing Knife*, *Ripping Saw*, *Half Ripper*, *Hand Saw*, *Pannel Saw*, *Sash Saw*, *Dovetail Saw*, *Mortice Guage*, *Mitre Box*, *Shooting Block*, *Streight Edge*, *Winding Sticks*, *Mitre Square*; and several others, which are likewise in common use, both with the Carpenter, and Joiner.

STAIR CASES.

Palladio, after observing that "great care ought to be taken in the placing of stair cases," so "that they may not obstruct other places, nor be obstructed by them", says that "three openings are required in stair cases; the first is the door through which one goes up to the stair case, which the less it is hid to them that enter into the house, so much the more it is to be commended. And it would please me much, if it was in a place, where before that one comes to it, the most beautiful part of the house was seen; because it makes the house (although it should be little) seem very large; but however, let it be manifest and easily found.

"The second opening is the windows that are necessary to give light to the steps; they ought to be in the middle, and high, that the light may be spread equally, every where alike.

"The third is the opening through which one enters into the floor above; this ought to lead us into ample, beautiful, and adorned places.

Stairs cases ought to be proportioned in width, and commodiousness, to the dimensions and use of the building in which they may be placed. The height of a step ought not to exceed seven inches, nor in any case should be less than four; but six inches is a general height. The breadth of the steps should not be less than twelve inches, if it can possibly be avoided; nor should they ever be more than eighteen; and to render the ascent free from the interruption of persons descending, their length should not exceed twelve, nor be less than four, except in common and small buildings, whose area will not admit of a staircase of more than three feet. That the ascent may be both safe and agreeable, it is requisite also to introduce some convenient aperture for light, which ought to be as nearly opposite to the first entrance to the stairs, as the nature of the building will permit. An equal distribution of light to each flight of stairs ought to be particularly regarded; for which reason, the apertures or windows are commonly placed at the landings or half spaces; though sometimes the whole is lighted from a dome. Staircases are of various kinds; some wind round a newel in the middle, while the risers of the steps are straight, and sometimes curved; others are of a circular plan, but form a well in the centre. The same may be observed of those whose plans are elliptical; the most common, however, are those whose plans form a square or parallelogram.

The ancients entertained a singular notion, that the number of steps ought to be uneven, in order that, when the right foot was placed on the first stair in ascending, the ascent might terminate with the same foot. This was considered as a favourable omen, on most occasions, and they imagined, that, when they entered a temple in this way, it produced greater and more sincere devotion.

Palladio, apparently actuated by this superstitious motive, allows the staircase of a dwelling house, eleven or thirteen steps to each flight. When a staircase winds round a newel or column, whether its plan be circular or elliptical, the diameter is divided into three equal parts, two of which are set apart for the steps and one for the column. But in circular or elliptical staircases which are open, or form a well in the middle, the diameter is divided into four equal parts; two of which are assigned for the steps, and two for the well or void space in the centre. Modern staircases, however, have often a kind of well of a mixed form; straight on each side, and circular at the returns of each flight. The openings of these wells vary in the point of width, but seldom exceed eighteen or twenty inches.

To most staircases it is absolutely necessary, both for convenience and ornament, to affix hand-rails; these generally begin from the ground by a twisted scroll, which produces a very good effect.

In the following observations, as illustrated by the various figures in the annexed plate, will be found a satisfactory explanation of their construction.

The diagram, delineated at *Figure* I, shews the plan of the first step, formed with a scroll to receive the newel post, and ballusters, of the twisted hand rail; a, forms the projecting nosing of the step; b, exhibits the thickness of the bracket, and c, points out the string board. In order to describe the scroll, take the distance between the points 1 and o, in-

in *Figure* 3, and lay it off from A to 3, in *Figure* 2, when divide this distance into three equal parts, in the points 1 and 2; next draw 3, 4, at right angles to A 3, and equal to four of the parts A 1: join A 4: then with centre 4, and distance 4 3, describe a circular arc, intersecting A 4, in 5, and divide it into twelve equal parts; finally, through the point 4, and the several points of division, draw the radii till they intersect the line A 3, as in 2, 3, 4, 5, 6, &c. which completes the scale for drawing the scroll required.

After the several radial lines 1, 2, 3, 4, 5, &c. in *Figure* 3, are drawn, take from *Figure* 2, the space 3, 2, and lay it from the centre O to 2, in *Figure* 3, then with the same opening, fix one foot of the compasses on 2, and with the other describe a small arc, as at C, when, from 1, with the same opening describe another arc, intersecting it at C. From the centre C, thus found, draw the arch 2, 1. Again from *Figure* 2, lay the distance 3, 3, from O, on the radical 3, with this distance obtain a centre as before, and describe the arch 3, 2, proceeding in the same manner with the rest. By contracting the line 4, 3, in *Figure* 2, it is evident, that a scroll may be drawn more open, or with less convoluti n, as in *Figure* 4; consequently, by increasing the length 4, 3, the scroll will acquire more convolution: and therefore the scroll, by these means, may be varied as desired. *Figure* 5, shews the pitch-board or raking, whereby the falling mould of the twist may be ascertained. The dotted lines, drawn from the hand rail to the pitch-board. display its width, which should be kept level, as it winds about. The lines a, 3, b, 2, continued round to D, express how much half the width of the rail rises on the pitch-board, from its first commencement to 3. The same pitch board is also shewn at D, and the method of finding the outside mould is likewise exhibited for the twist of the hand rail, after its sides are so squared, as to be every way in a perpendicular direction to its ground plan. This, however, cannot be effected, unless the proper mould for the hand-rail, be previously found, which may be done thus. Let B, in *Figure* 6, be considered as that part of the plan of the hand rail, comprehended between 1, 3, in *Figure* 3, and D, the pitch board, which shews the rake or bevel of the hand rail; after this has been divided into any number of equal parts, let ordinates be drawn to the plan B, as a, b, &c. when from the raking line e, d, draw the corresponding ordinates at right angles with it; and with the compasses transfer the several ordinates from 3 to G, as a, b, to c, d, and 1, 2, 3, 4, respectively; then, by tracing a curve line through these points, G, will be an accurate mould for the upper side of the hand rail. But from the twist of the hand rails requiring a greater substance of wood than the straight part, it may easily be determined thus: delineate the square of the hand rail on the pitch-board, as a, in *Figure* 7, when parallel lines drawn from the opposite angles, will shew the thickness required, as at 1, 2. In conformity with this, l, m, n, in *Figure* 8, points out the manner of glueing up the rail, with the necessary additional thickness of wood, before described.

This additional thickness is composed of so many pieces, and so varied in glueing, in order to assist in the more easy formation of the twist. The best method of glueing these, we are acquainted with, is to effect it in the straight way of the grain, when, if the wood be properly matched, the whole will appear to be one solid piece.

To reduce these pieces in a proper manner, and to enable the whole twist to present an agreeable appearance to the eye, it will be necessary to have a falling mould, in order that, when each part of the twist is so squared, as to answer in every part, to a perpendicular line over its plane, when placed in its proper position, the mould may be applied to the outside of the rail round the twist. Hence, in *Fig.* 5, consider D as the pitch board and O P as the level of the scroll at 3, 4. When take the stretch of a line supposed to be girted from 1 to 3, in *Fig* 3, which transfer to O P at D; then divide each side of the angle formed by the raking and level line, into any number of equal parts, as 1, 2, °, each way, and the points produced by the intersections of the lines drawn from each division, will form a curve, perfectly easy, and sufficiently accurate for the purpose required.

If a scroll be required to take its spring from any part of the second step, let the pitch board be drawn as at *Fig.* 6, after which proceed in every particular as before. *Fig.* 9, represents the plan of a hand-rail, which includes five steps. M, denotes the quarter plan, D the pitch of five steps; and R the face-mould for the hand-rail, if it is intended to be cut out of the solid; if otherwise, thin veneers should be glued round a cylinder, constructed for the purpose, on which each step and riser must be marked, as shewn at A, in order that the thin slips at b for the hand-rail, and those at a, for the string-ing-board, may be laid down correctly

To illustrate this subject as much as possible, we present our readers with several different kinds of staircases.

Figures 10, 11, 12, 13, 14, 15, 16 and 17 in *Plate* 1, and *Figures* 1, 2, 3, 4, 5, 6, 7 in *Plate* 2, exhibit the plans and sections of different kinds of staircases; all of which may be constructed upon true geometrical principles, and which will be found, when executed in a workmanlike manner, to comprise some of the finest, and most ingenious parts, of the elegant art of Joinery.

From this variety of plans for staircases, it will be no difficult task to select such, as may be adapted to almost every species of building from the rural cottage to the magnificent villa; but the following

ing general rules should be attended to before any kind of staircase is erected. It will be necessary to consider, first, the height of the floor to which the staircase may ascend, secondly the rise and number of steps necessary for the height, thirdly, the best mode of dividing the number of steps by such half-spaces, (or breathing places) as may be required on the way, fourthly, the height of the space above the head, commonly called the head-way, and lastly, whether the breadth of the ascent be proportioned to the whole building, and sufficient for the purpose intended; so as to avoid the inconvenient meeting of persons ascending and descending at the same time. A staircase should in all cases, where practicable, be liberally supplied with light, in order to avoid slips, falls, &c. this light may proceed either from the sides, from a sky-light, or a cupola at the top, according as the nature of the situation will allow.

Previously, however, to the commencement of the work, it will be proper to delineate a plan of the intended stairs, and to lay out the whole in ledgement, which may be effected as follows.

Admit that the parallelogram A B C D *fig.* 8, represent the plan of a rectangular staircase; when respectively draw a b, b d, d c, and c a parallel to A B, B D, D C, and C A, and at a distance from them, equal to the intended length of the steps, which may be from three feet to ten or twelve feet, as may be required, and within it draw the thickness of the hand rail. Next let d b, b a, and a c be divided into such a number of steps that the aggragate of their several heights may be equal to the whole height to be ascended; when, take the sum formed by the heights of the several steps included between d and b, and at the distance draw G F parallel to B D.

Join F E, and produce the plan of each step, to meet it; then set up the heights of the first step, and draw it parallel to B E, until it meet the base line of the second step, next set up the height of the second step, draw it parallel to B E: and proceed in like manner to set up the heights of all the remaining steps unto F.

Next after making B I equal to B G and drawing I K parallel to A B, at the point K begin to set up the steps unto the point L, and draw L M parallel to N O; make N M equal to N O and draw O S parallel to A C; at P begin to set up the steps, as before, unto Q, when Q T will be equal to the height of the story, and the several figures B G F E, B I K L M N, together with A O P Q R S C, will shew the several sides of the staircase laid out in ledgement, as required.

If the workman examines and considers the preceding example in an attentive manner, he will soon learn to lay down any other staircase in ledgement.

Mr Price offers the following observations on the forming of scrolls, &c. &c.

"First, form a scroll with chalk, or a pencil, agreeable to the bigness of the place in which it is to stand; next resolve on the bigness of your stuff to be used for your rails, and also your mouldings on the side thereof as in C. Let d, be the center of your chalked scroll in D: on which describe, with the projection of your mouldings from C, the small circle d; take from C half the bigness of the stuff, as e, g, or e, f, which add to the small circle, and form the circle l., i, t; which is the bigness of the eye of the scroll. This done, take the distance from i, to the inside of the rail, as the supposed chalked scroll, which suppose k; with it, make a diminishing scale, by setting that distance up, from t, to l; draw the line k, l; place one foot of your compasses in k, descibe the part of a circle t, 8; which divide into eight equal parts, because here your supposed chalked scroll was to come into its eye, or block, at one revolution of a circle. Scrolls may be made to any number of revolutions desired, by the same rule; Witness that above in *Figure* E.

"Place one foot of your compasses in d, describe the large circle w, l, l, u; which always divide into eight parts, because you strike one-eighth part of a circle every time, till you come into the eye, or block i, t, h; from the said divisions on the large circle, draw lines through, for on them your sections meet, which form the scroll. It is observable in drawing your sections, that they dont end in the line drawn through the great circle, only the outside scroll; for those of the inside scroll end on a line drawn to each respective center. I suppose A, and B, to be two steps: the rest I think cannot fail of being understood, by observing the letters and figures, which shew each part distinctly.

"In order to make the squaring of a twisted-rail easy, see the plan F, which is the same as that in the foregoing, find the point of touch b. From these curves a mould must be traced out, in order to form a sweep, which when applied on the rake, is agreeable to this of a, b, c, d, as that of K. (It is first to be observed that you will want wood extraordinary, both on the top of the rail, as in L, at e, a; and also under the same, as g, h.) To find which observe where your sweep begins in the plan F, as at a, c; also observe, that o, and n, is the end of the twisted part. Therefore from a, to n, divide into a number of equal parts, so as to transfer them on some line, as in M, from a, to n; also divide the inside of F, as from c, to o, into equal parts, so as to transfer them on some line, as in N, from c, to o; take the distance e, a, in F; apply it to the pitch-board. as from g, to e; take the pitch board I, with it place e, to c, in N; draw the line d, q, and make the point s; divide from d, to s, into eight equal parts, also from d, to o, into the same number; draw the lines which form a sweep, whose use shall be hereafter shewn.

Likewise take the pitch-board I, and apply e, to a, in M; draw the line e, p, and make the point r;

from

from e, to r, divide into eight equal parts; also from e, to n, do likewise; draw straight lines from each division; that curve shews how much wood is wanting on the back of the rail, as b, t, which describe in L, from e, to a; and there describe the bigness of the rail; which shews how much wood is wanting, as may be observed by what was said above. The other part of the twist is cut out of a parallel piece, as O. Which thickness extraordinary is shewn in L, at e, a.

"To square the twisted part of the rail, having so much wood extraordinary on the top and bottom, observe in F, from a, to e, and from c, to f, must be traced, as was above mentioned. Take a, e, in F, apply it to the pitch-board I, it shews g, i, which length place in K, from k, to i; also take from F, the distance b, d, apply it to the pitch-board I, it shews g, m, which length place in K, from l, to m. This done, trace out the raking mould K, agreeable to the plan F, which by inspection, and a little practice will become easy, and without which nothing is known truly. I say the wood extraordinary being accounted for in L, both on the top and the bottom of the rail, observe to place your stroke f, in its true place, that is, at the beginning of the twisted part; take the raking mould K, set i, to f, in L; there strike it by; with the angle of your pitch-board describe the pricked line f; by the side of the rail, then apply the mould K, to the bottom; set i, to this pricked line, and there describe by it, with your pencil; lastly, cut that wood away; also cut the remaining part of the scroll out of the block, as O; then glue these together, and bend both moulds, M, and N, round the rail; strike them by that, and cut the wood away; so will the back of your rail be exactly square, and fit to work.

"You are always to observe this general rule, viz. to conceive each respective paragraph as it occurs, before you begin another; the neglect of which, appears by some who cannot conceive the particulars of the foregoing plate, although I had put it in so clear a light.

"I have here described three distinct methods of squaring the twisted part of a rail, which may be known, and the rail squared, with more ease than in the foregoing plate. But when done, they will not have that agreeable turn, in their twisted part, as they would have, if done by the foregoing unerring rule, as may more clearly appear, by the following explanation.

"That of P*, is the raking mould, taken from K, (whose use and application was therein clearly shewn;) that of Q*, is the pitch-board, taken from I, which gives the rake, or declivity of the rail.

"In R*, is shewn how to square a rail, without bending a templet round the twisted part thereof; and which is by being guided by the back; first describe the bigness of the stuff to be used, as a, b, h, i,; which shews how much wood will be wanted at bottom; supposing S*, to be the side of the rail. And because the grain of the wood should be agreeable to the falling of the twist, therefore consider how many thicknesses of stuff will make the wood required to cut the twist out of; as here three. Therefore as in S*, continue the line a, b; place one foot of your compasses in a, make the section, or part of a circle c, d: divide it into four parts, as 1, 2, 3, 4, because the rail S*, must be always reckoned as one; this by inspection shews how the grain of the wood is to be managed, as appears by the shape of the several pieces, T*, U*, W*, which are better if cut so by the pitch-board, before glewed together."

"In X*, is shewn how to square the twisted part, making the bottom your guide; the section shews how much wood is wanted on the back.

"In Y*, is shewn how to square the twisted part, making a middle line on the back your guide; the section shews the wood wanting on the back, and at the bottom.

That of Z*, may be cut out of a parallel piece, of the thickness of the intended rail, which when it is glued to the twisted part, will want little or no humouring.

"N. B. There is a nicety in working the mitre thereof, as k, l, m."

"You are to observe, the foregoing plates must be well understood, and then, in this *Plate* (3), the lengths of the newel, and ballusters that stand under the twist or scroll are truly described; that is, their length and bevels may be known before the rail be put up in its place; and that it may prove easy, observe the plan of the twist or scroll is the same as before, and so are the two steps P, and Q, and the pitch board R.

First, resolve on the bigness of your ballusters, as a, b, c, d, e, f,; and also the newel. Divide the said ballusters truly on a line drawn in the middle of the rail; for then, what is wide on one side, is narrower on the other It is for that reason I chuse to divide them on a middle line. Describe the plan of the ballusters, as p, q; r, s; t, u; u, w; x, y; and z; for there your twisted part ends; from thence to the eye is level.

"Observe where your scroll begins, as at l; and on some line, as above, in V; first make a point at l; then from your plan take the distances p, q: r, s; t, v; u, w; x, y; and z; which transfer, as above, observing to have regard to place truly each distance from l, both ways, as p, q; r, s; t, v; u, w; x, y; and z.—Observe also, to take from the plan the distance from l, to m, which apply to the pitch board R, as from h, to n, which gives the length h, o; take this pitch board, and apply it on the line above, which by inspection the letters will shew; this gives the slope of the rail, as h, o, &c. From o, to h, and form h, to y, from the curve by equal divisions, and drawing straight lines, as was before shewn.

"Lastly,

"Lastly, having the lengths of your fixed ballusters, as a, b, describe the steps S, and T, with the pitch board. So that by continuing perpendicular lines, from the points on the line first terminated, to the said curve, and to the steps, you have the accurate lengths of the ballusters, as a, b, c, d, e, f, the newel g, being the same length as f, because at f, or z, the twisted part ends.

"The curve of the first, or curtail step P, is formed by the same rule as delivered for the plan of the rail.

"It may not be amiss to observe, particularly the point of the sweep, or curves beginning, and being particular also in its application, by which this, and the foregoing, though represented with but two steps is the same in fact, as though I had described a whole flight, to shew its use.

He further observes, that "zealous to promote what may be useful, in this plate, I have made easy the difficulty of squaring a rail that ramps on a circular base.

"Observe, W, is the plan of a stair case; and at the landing is a quarter circle; to make this easy; in X, is three steps, described by a larger scale. Likewise in Y, is the plan of the rail, as was before shewn in *Plate* 2. A considerable thickness of wood more than usual, is required on the back of this rail, as in &, at p, b; which will appear more plain by inspecting *Plate* 2; as also the method to trace your moulds that shall bend round the said rail. Let the sides be squared as was shewn in *Plate* 2. Observe here in *Figure* 2, the line k, p, o; take the distance k, p, and place it on some line, at pleasure, as in Z, then divide the outer circle in Y, into a number of equal parts, as into six, as from g, to h, which transfer to Z, as g, 1, 2, 3, 4, 5, 6, h. The point of the ramp may be observed to fall within the fifth division, as at s, so that by the intersection of straight lines, and equal divisions, you describe the sweep for the ramp g, b, which makes Z, the mould to bend round the outside of the said rail.

"Observe also in Y, from b, to f, divide it into six equal parts, which transfer to &, as from e, to f, (and observe again,) the ramp falls within the fifth division, as at r. So divide the distance from e, to g, and from g, to h, into equal parts, and by drawing straight lines, you have the sweep b, e. From the point b, to p, is the thickness you want to be added, extraordinary to the back of the rail &, and which is the inner mould; so that by bending both these moulds round the rail, and by drawing them with a pencil, and cutting away the superfluous wood you have an exact square back. There seems no difficulty now left, unmentioned, to square twisted rails in any form whatever.

"Because I have all along strove to give variety, observe M; in which is shewn a method to have your newel under a twist, the same length as the rest; by which means also the rail twists no farther than the first quarter, and consequently the remaining part may be cut out of a plank, of the thickness of our rail, without twisting at all. There seems no explanation wanting to clear this point, but inspection, and a good conception of *Plate* 2. In this of M, l, f, is the thickness of wood extraordinary wanting on the back of the rail.

OF DOORS AND WINDOWS.

In forming the apertures of doors, whether arched or quadrangular, the height should, in general, be about double their breadth, or a little more. It was necessity, most probably, that gave birth to this proportion, which habit has confirmed and rendered absolute. The disposition of doors and windows, and assigning to them their proper dimensions, according to the purposes for which they are intended, are not the business of the Joiner, but of the Architect; for which reason we shall here advert only to the common method of decorating doors and windows, the former of which have an architrave, around the sides and top of the aperture, with a regular frieze and cornice upon it. In some cases, the cornice is supported by a console, on each side of the door, and sometimes, besides an architrave, the aperture is adorned with columns, pilasters, &c. which support a regular entablature, with a pediment, or with some other termination, either in architecture or sculpture. Front doors, intended to be ornamented with any of the orders, should not be less than three feet six inches wide; the height should be twice the width and one sixth part more, which might also be the height of the column; the abacus may be then taken out of that dimension, in order to separate the door from the fan light. The windows of the principal floor are generally most enriched. The simplest method of adorning them is, with an architrave surrounding the aperture, and crowned with a frieze or cornice. The windows of the ground floor are sometimes left entirely destitute of any ornament; at other times are surrounded with rustics, or a regular architrave having a freize or cornice. The windows of the second floor, have generally an architrave carried entirely round the aperture; and the same method is adopted in adorning attic and Mezzanine windows; but the two latter seldom possess either frieze or cornice; while the windows of the second floor are often crowned with both.

Mr Price offers the following observations on the proportions necessary to be observed in ornamenting doors, windows, &c.

The width of either being given, make its height equal to two diameters; or two diameters and a sixth part; which, is esteemed as the best proportion. The said width being made as the use and conveniency of the place allows, divide it into six equal parts, one of which is for the architrave as in R; *Plate* 4, which being divided into four equal parts, three give the height of the frieze S; and five, such parts

parts give the height of the cornice T; all which is easily conceived by the scale, therefore to my thinking can want no explanation, otherwise than due inspection.

"Again, admit that of V, was an architrave proportioned as before. U, being the frieze, and W, the cornice, the method is as before, (the ornaments only varying:) these members will be easily conceived, by duly inspecting the scales; and as to the curves of each moulding, enough seems to have been shewn in the foregoing plates.

"N. B. The first face of the architrave should be as far from the frame of the door, or window, as the breadth of the whole architrave; observe also that this proportion is taken from the width between one architrave and the other, as will be shewn in its due place.

"Admit the architrave X, were one sixth part of the opening: which being divided into four parts, as before, the frieze Y, has three such parts, and an half, as appears by the scale; and the cornice Z, has five parts as in the other examples. Each of these cornices projects equal to their height; and the frieze in all being formed by an equilateral triangle, made with one third part thereof, gives the projection of the architrave; whose parts are shewn distinctly, by the scales.

"The architrave A, being one sixth part of the opening; is divided into four parts; of which, the frieze B, has three and one fourth; and cornice C, has five such parts. So that here are four manners of forming the ornaments of doors and windows according to Palladio.

With regard to the hanging of doors, shutters, or flaps with hinges, care should always be taken to place the centre of the hinge in the middle of the joint; but, as in many cases there is a necessity for throwing back a flap to some distance from the joint; the distance between the joint, and the intended point, must be divided into two equal parts, which point of division will denote the situation of the centre of the hinge. Sometimes doors are required to be hung in such a manner, that when folded back, they shall be at a certain distance from each other, as is frequently desirable in Churches and Chapels, this may be easily effected by hinges, with knees projecting to half that distance.

In all elegant rooms, it is necessary to contrive, that the doors when opened, should pass clear over the carpet; now, it is evident, that this cannot be the case, if the jamb on which the door hangs, is truly perpendicular, and the bottom of the door is close to the floor, as the bottom of doors commonly are. An inconsiderate observer might recommend a part of the bottom of the door to be cut off, in order to permit its free passage over the carpet, but still, when the door is shut, an open space will intervene between it and the floor, unless as in some cases, the carpet is continued through the opening of the door to an adjoining passage or room. When this is not the case, the room will be rendered cold and uncomfortable; and the necessity of contriving some method to remedy the defect, becomes immediately obvious. This remedy may always be found by hanging the door with rising hinges, constructed for the purpose, with a spiral groove, which winding round the knuckle as the door opens, gives it a free passage over the carpet. Hinges, however, thus constructed, requires that the door should be bevelled at the top next to the ledge or door catch, in proportion to their rise at one quarter of their revolution.

This is the most elegant and effectual mode of enabling a door to bear the carpet; but various other modes were made use of, before the discovery of rising hinges. Such as raising the floor under the door, as much as the thickness of the carpet might require. Making the knuckle of the bottom hinge project an eighth of an inch beyond the perpendicular direction of the top hinge,—fixing the jamb to which the door might be hung, about the eighth of an inch out of the perpendicular: and placing a common butt hinge at the top, and one with a projecting knee at the bottom.

These modes may be practised on common occasions, but where elegance and accuracy are required, the former method is entitled to a decided preference.

We proceed now to quote from the before mentioned author "*The Proportions of Pediments and their Dependants.*

To raise the pitch, or slope of a pediment, with grace and beauty, says Palladio, divide the width given into nine equal parts, two of which will be its perpendicula. height, as in D; for, says he, if it rise one fourth of its width, it will be too high; and if one fifth, it will be too low. Therefore the most comely proportion, will be two ninths as before.

"And in consideration that no pediment can be performed without two kinds of cornice, (except it be kneed at its bottom or springing, which is reckoned a kind of defect,) therefore to give each of the cymas such a shape or curve, as shall agree in their miter, do thus. Describe the curve of the level cornice F, (*Plate* 4,) as a, b, c, by two such portions of circles, as that the centers for forming each, may be on an horizontal, or level line, drawn through the middle of the said cyma; as * * c, d; being the projecture thereof. Draw lines from the points of the said cyma, agreeable to the slope of the pediment, which gives or terminates the bigness of the raking cornice or cyma G; so that by drawing a line through the middle of the said member, on it are the centers * *, by which the curves e, f, g are described; the projecture g, h, being as before. In case a break or return be made in the pediment, then another kind of cyma must be formed, which shall agree with the two former, as H, the centers

centers for forming each curve, being on an horizontal line drawn through the middle of the cyma, as before; i, k, l, is the curve whose projecture as before is l, m; these three kinds of cornice being thus formed, will agree with each other, without the trouble of tracing. But if the given curve be not described as before, then observe the method proposed in I; by which the curve of any raking moulding whatever, may be truly described. Admit the cornice given were K; n, o, p, being its curve, and p, q, its projecture; by making points on the said curve, draw lines from them, agreeable to the slope of the pediment, on which place each respective projecture from K, to L, so is r, s, t, its curve, the projecture being t, u, as before. And if a break or return be made as M, then transfer the several projectures from K, observing that the points be on the lines drawn agreeable to the rake of the pediment, so will w, x, y, be the curve, and y, z, the projecture as before; which no doubt but inspection explains.

LAYING OF FLOORS.

The chief excellence of a floor, consists in its being perfectly level, and no higher in any one part than another; but experience teaches, that this desirable object must frequently be sacrificed to considerations of convenience. The mode recommended for hanging doors, furnishes a sufficient proof of the correctness of this observation. A frequent defect is observable in floors, (the origin of which may be attributed to the carpenter) arising from their sinking in the middle, or in those parts that are unsupported, which circumstance demonstrates how necessary it is that every floor should possess a certain degree of camber, in order that when it settles or the moisture has exhaled, it may be as near to a plane as possible.—When the joists are depressed in the middle, it will be proper to fur them up; on the contrary, when they project in the middle, they ought to be reduced by the adze; the former however, is most generally the case.

The joints of flooring boards, are either square, plowed and tongued, rebatted or dowelled; the boards being nailed on each edge, when the joints are square, or plowed and tongued; but when the dowel work is executed in a proper manner, the outer edge only is nailed, and this is effected by driving the brad, in an oblique direction, through the edge, without suffering it to pass through the upper surface of the board. The headings are in some cases square; in others splayed or plowed, and tongued.

GROUNDS,

Are pieces of wood fixed to the wall around doors, windows, &c. for the purpose of receiving the architraves; they are also fixed in different positions in rooms, in order to receive the various kinds of mouldings required in ornamenting the same, such as bases, surbases, chimney pieces &c. &c. Now as nothing has a more dissagreeable effect to the eye, than the untrue appearance of any work of this kind, it is absolutely necessary if the workman would avoid deformity, to fix all grounds in a true vertical position, both on their edge and face, and in a firm and solid manner to the wall.

OF GLUING UP THE BASE, SHAFT, AND CAPITAL OF COLUMNS.

To each order belongs a particular kind of base, and the first operation required, is that of gluing up the base.

Figure 1, *Plate* 5, exhibits the mode of mitring the bottom course together, which must be effected on a perfectly flat board, and by fitting all the joints as close as possible. When the course has been well glued together, and secured on the inside with blocks at the several angles, the top of the course must be planed quite smooth and out of winding; after this, the next course must be glued on, and the joint must be broken in the middle of the under course, (as shewn by the dotted lines in the plate) by which means as many courses can be glued down as may be required. When the whole is thoroughly dry, the operations of the turner may commence.

The shaft of a column should be glued up in eight or more staves, according to its intended dimensions; but care should be always taken to have the joint in the middle of a fillet, and not in a flute, which would impair its strength very much.

Figures 2, and 3, shew a plan of the upper and lower ends, or the horizontal section at top and bottom. If eight pieces are sufficient to form the column, let an octagon be described round the ends, and let lines be drawn from each angle of the octagon to the centre; when the bevel of the edges of the staves will be given for the joints, which must be quite straight from top to bottom, though the staves be narrower at the top, as shewn in *fig*. 3. These staves must be of sufficient thickness, because their outsides have to assume a curvature proportioned to the swell of the column by means of a diminishing rule; next glue the pieces together one after the other as the glue dries; block them well at the corners in the inside, which will greatly strengthen the joints; and proceed in this manner to the last stave; but all the blocks must be glued on and dried, before the last stave can be fastened. Pieces, however, may be glued quite across for the last stave, and fixed to the inside of the two adjoining staves, or they may be fixed by screws to each stave: in which case the under side of the last stave must be planed so as to rub well on the cross pieces.

When the stave is put in, and glued upon the cross pieces, it may be driven tight home, like a wedge, and the whole will be firm and substantial throughout; great care, nevertheless, ought to be taken, as to preparing the staves and blocks out of

wood, thoroughly dry, because, after the lapse of some time, if the wood be moist, the column will be in danger of falling to pieces at the joints. It will be necessary also to make each piece according to the plan, for a trifling error in any one piece, will make a very material difference in the column after gluing. When the glue used in combining the column is dry, the angles must be regularly worked off all round; and the column will then have double the number of sides, or cants, bearing a proportionable regularity to each other. Proceed in a similar manner to work off the angles as before, so as to make the sides, or cant of the column quite regular. Lastly, let a plan be formed, in order to fit the curve of the column at the bottom, or render it rather flatter, then round off all the angles, until the surface of the column is perfectly smooth. One thing to be observed, with respect to the moulds employed in jointing the staves together, is, that they cannot be considered as exactly true when applied in a direction perpendicular to the joint. The most correct mode, is that made use of in finding the backing of a hip rafter, which has been already noticed; but this exactness, nevertheless, is not always attended to, in consequence of the difficulty of discerning the deviation in some instances. When the column is quite finished, it should be well painted, by way of protection from the effects of the weather.

Sometimes columns are glued up in two halves, in which cases those two halves are glued together, and the blockings are introduced a considerable way by hand; but if the column be too long, a rod of sufficient length may be used. Both these methods have some inconveniences, which cannot be avoided; by the former method, the last joints cannot be rubbed together from the obstacle presented by the tapering of the stave; but if this be glued quickly, it will be pretty sound; by the latter method there will be an uncertainty of the blockings being sound. In all cases, however, care should be taken to place the grain of the blocking piece in the same direction as the grain of the column, so as that they may both expand and shrink alike, when affected by the weather.

OF GLUING UP THE IONIC CAPITAL.

Figure 4, represents the mode practised in gluing up a capital. The parts denoted by B B, &c are triangular blocks of wood, glued upon the front, in order to complete the angular square: upon them the pieces A, A, A, &c. are glued, and this is considered the best method of gluing up the capital. Another method is, to glue the triangular blocks C, C, at the angle of the abacus, then the four sides of the abacus as D, E, F, may be made of one entire length, and mitred at the horns, or they may have a joint in the middle of the abacus, where the rose is placed, as the workman shall think fit: this method will do either for a column, or a pilaster.

Figures 5, and 6, are designs of shop fronts.

Figure 7, shews the method of bending a cornice round the internal part of a circular body on the spring.

Figure 8, exhibits the mode of bending a cornice round the external part of a circular body. On the spring, draw the lines A B, to the centre of the body C B; and describe the arch line D E, G F, which will be the edge of the cornice, when bent straight round the body.

Figure 9, exhibits the mode of describing angle bars, for shop fronts. A, represents a common bar, and B, the angle bar, which is of the same thickness and placed in its intended position; draw a, a, perpendicular to a, m, intersecting the side of the angle bar in a, then take the distance a, a, on the angle bar, and lay it from a, on the common bar, so as it may intersect its middle in a, also; join the points a a, and draw b b, c c, d d, &c. in the same in a parallel direction to a a; next, draw from the points b, c, d, &c. in A, the dotted lines b b, c c, d d, &c. to intersect the middle of the angular bar in b, c, d, &c. then lay off from these points in the angular bar, the several distances b b, c c, d d, &c. respectively equal to b b, c c, d d, &c. in the common bar, which, on being traced out will give the proper form of the angle bar.

END OF CARPENTRY AND JOINERY.

CARVING

CARVING AND GILDING.

The operations of carving and gilding are usually connected as one trade, though in fact they are totally distinct branches of manufacture, performed by different persons, and generally in different houses. The art of gilding depends chiefly on the materials made use of, but in carving much ingenuity is required on the part of the workman, if he would excel, and obtain the reputation of a designer as well as the character of a mere workman.

Carving.—Is the art or act of cutting or fashioning a hard body, by means of some sharp instrument, especially a chisel. In this general sense of the term, it may be said to include statuary and engraving, but our business is with carving in wood. To do this the figure or design should be either modelled in clay or drawn on the wood to be carved. When the design is drawn on the block intended for use, the other parts of the wood which are not covered by the lines of the designs are to be cut away with instruments, as chisels, sharp pointed knives, &c. adapted to the purpose. The wood that is best fitted for fine carving is that which is hard, tough, and close, and to prepare it for the business, and for receiving the design, it must be washed over with a mixture of white lead and water, by which it will take the ink or crayon, without the smallest difficulty. Sometimes the design is drawn on paper, and pasted on the block; in this case the whitening is omitted, and it is sufficient if the wood be planed smooth and even. Then moistening the figured side of the design with a solution of gum tragacanth in water, the workman puts it very evenly on the block, and when it is quite dry, he wets it slightly, and frets off the surface of the paper gently, till all the strokes of the figure appear distinct. It is now adapted to the operation of the carver, or the cutter in wood.

Carving in wood has long been in the background, as a branch of the arts, nor can this be wondered at, when the methods in which it is commonly taught and practiced are considered. A boy with very little education, and no previous knowledge in drawing, is bound apprentice to a carver, and is expected to go to his bench and follow the beaten track of those who are acquainted only with the practical part of the trade, and who can give no reasons for the rules which their experience suggests. Among the men who are at all capable of instructing the boy in a proper manner, there are very few who will take much concern or trouble about the business. They are indeed, sometimes generous enough to tell him that it is only by gaining a competent knowledge of drawing and modelling, that he can succeed; and advise him to devote his leisure hours to this purpose, a sacrifice which a youth is seldom inclined to make, and therefore at the end of seven years he is sent into the world as a carver, with as little knowledge as those whom he has been obliged servilely to imitate during the whole of his apprenticeship. This ignorance might have been fully obviated, if the youth had been previously instructed in drawing and modelling, by means of which a person would attain much higher degrees of perfection, in carving, in in the short space of two years, than those who have practiced for twenty, without these advantages. There are only eleven master carvers in London, and about sixty Journeymen (though at one time there were six hundred) many of the latter are now very old. They make no shew of their work, and live only in private houses. In trade they are principally known to the upholsterers, are a distinct class from those who keep shops and write "Carvers and Gilders" over their doors, for it can be proved, that hundreds of the latter never saw a carving tool in their lives.

Enough has now been said to shew that in order to obtain perfection, or indeed any real knowledge in carving, it is necessary to have a sufficient knowledge of drawing to make a good sketch, and to be able to model what is required to be carved. Modelling clay is prepared and sold at the potteries, and requires only to be kept damp. Carving in wood is principally confined to foliage, shells, scrolls and such like ornaments. A leaf appears to be one of the best subjects for a carver to model. He should copy from nature, and select one, the form, undulations and terms of which are pleasing to the eye. The dock leaf and that of the rhubarb plant, are admirably adapted to the purpose. On a piece of wood about half an inch thick, and of a size proportioned to the leaf to be copied, the clay must be formed into a rough imitation of it; the fingers are at first the principal tools to be used, yet for those parts which they cannot reach, and those touches which they cannot accomplish, it will be necessary to use a modelling tool. Having succeeded in modelling the subject to be carved, it will be

necessary

necessary to make the mould, and cast it in plaster of Paris, for the clay is difficult to preserve, unless baked in a kiln. The mould is made in the following manner; plaster of Paris, which easily mixes with water, should be made of the consistency of thick cream, and should be spread all over the model. When the plaister is set, the board should then be removed, the clay picked carefully out, and a mould will be obtained, called a waste mould, which must be left in cold water for a quarter of an hour. When used as a cast, it should be rubbed over with a mixture of hogs lard, and the droppings of sweet oil. The plaster of Paris is to be mixed as before, and poured into the mould, which afterwards should be knocked off with a chisel and mallet, by small pieces at a time, a leaf will then appear of the same form as that modelled in clay, which the carver may proceed to copy in any sort of wood, but lime tree is the best suited to beginners.

The tools used for carving, are of various forms and sizes; the best, and indeed almost the only ones that are fit for use, are made by Mr. Addis, of Deptford, but they are sold by different ironmongers in London. In proceeding to carve, it is best to make a rough sketch on the wood, which can be afterwards paired to the outline; for all small work, the superfluous wood may be cut away with the tool in the hand, but when large, a mallet will be necessary; the hand will soon, by practice, become accustomed to the use of it.

Carving is most interesting work, and a person soon gets a zest for it, and is astonished to see what a few cuts will produce, if copied from a good model made by his own, or some more skilful hand. Many carvers can produce common figures, but to carve the human figure, it is necessary to know Anatomy, for without that knowledge, though the figures may be called pretty by those who cannot distinguish the defects, to others who are good judges, they will appear poor, and sometimes highly ludicrous.

The operation of carving may be greatly assisted by an instrument similar to one used by sculptors, and called a gallows, which any common joiner can make (*see Plate Miscellanies, Figure* 1). A, is a slide that moves over any part of the model, B B, another that can be raised or depressed, to get the heights and depths, and is fitted to them by means of a screw. The method of using this instrument, is easily understood, and is very simple; it is merely held in the hand, and rests upon the two legs C C.

In sharpening the tools, care must be taken to bevel them equally from both sides, the large ones on a grinding stone, and the small ones on a rag stone; they must be set with slips of Turkey stone; four sizes will answer all sorts of tools. To sharpen the inside of the crooked tools, a little machine much resembling a common spinning wheel, is used, the wheel of it should be about fourteen inches in diameter, a handle should be affixed to turn it, the spindle should be square, with small circles of lead fitted on it shaped according to the sweep or form of the tool; a little sand and water facilitates the sharpening. The carvers make this machine for their own use, for the value of a few shillings.

GILDING.

The art of *gilding* or laying a thin superficial coating of metal on wood, and other substances, has been long practised and highly esteemed, both for its utility and the splendid effect which it produces. Gold, from its great beauty, and from the length of time during which it may be exposed to the action of the air without tarnishing, is unquestionably the most valuable of all substances for the purposes of decoration; but on account of its great price, and weight, it can only be used, for general purposes, in the shape of a fine skin, or leaf, as it is usually called. Gold is the most malleable and ductile of all substances, and therefore a given weight of it, notwithstanding its high specific gravity, may, by beating, be made to cover a larger surface, than an equal quantity of any other body whatever

The different states in which gold is used for the purposes of gilding, are the following; (1) in the shape of leaf gold of different degrees of thickness, and formed either of the pure metal, or of an alloy of this with silver; (2) as an amalgam of gold; and (3) in gold powder.

The leaf-gold is procured by the gilder from the gold-beater, whose art consists in hammering a number of thin rolled plates of the metal, between skins or animal membranes,

The amalgam of gold is made by heating in a crucible, some pure quick-silver; and when it is nearly in the boiling state, about the sixth part of its weight of fine gold in thin plates, heated red hot, is to be immersed in it. The mixture soon becomes homogenous, and then it is allowed to cool. When cold it is to be put in a piece of soft leather, and by gradual pressure, the fluid part of the amalgam consisting almost wholly of mercury, may be forced through the pores of the leather, while the gold, combined with about twice its weight of mercury, will remain behind, forming a yellow silvery mass of the consistency of butter. This, after being bruised and ground in a mortar, or shaken in a strong phial, with repeated portions of salt and water, till the water comes away quite clear and unsoiled, is fit for use, and may be kept for any length of time, without injuring, in a corked phial.

It is of the utmost importance, that the materials of this amalgam, and especially the mercury, should be perfectly pure, as the least portion of lead or bismuth would very materially injure the beauty of the gilding, by deteriorating the colour of the gold, and filling it with black specks.

Gold in powder, is prepared by three different methods; the first and most simple is, to put into a glass or earthen mortar, some gold leaf, with a little honey,

honey, or thick gum water, and to grind the mixture for a considerable time, till the gold is reduced to extremely minute fragments, when this is done, the honey or gum may be washed away, leaving the gold behind in a flaky or pulverulent state. A more effectual and quicker method of reducing gold to a state of powder, is to dissolve it in Aqua Regia, or, as it is denominated in the new chemistry, in nitro-muriatic acid, and then precipiate it with a piece of copper. The precipitate, after being digested in distilled vinegar, and then washed with pure water and dried, is in the form of a very fine powder, and is said to work better, and is fitter for burnishing than the powder obtained from leaf-gold. The very finest ground gold is produced by heating very gradually the gold amalgam, already described in an open earthen vessel, and containing the fire till the whole of the mercury is evaporated, taking care that the amalgam shall be constantly stirred with a rod of glass, to prevent the particles of gold from adhering as the mercury flies off. When the mercury is completely evaporated, the residual gold being then ground in a Wedgwood-ware mortar, with a little water and afterwards dried is fit for use.

Gilding is performed either with or without heat. By the first of these methods, those substances are gilt which are not liable to alteration, by exposure to a moderate heat, such as metals, glass, and porcelain. The second method is practised with those substances as wood, paper, lead &c. which would be destroyed by being raised to a temperature requisite for gilding the former. Our business is chiefly with wood.

Gilding on wood, both in oil and burnish, is at present at its highest perfection, and is executed in London, better than in any other part of the world. That which is brought from France and other parts of the Continent, is by no means equal; not that it is to be inferred from hence, that gilding is well executed by all who undertake it in the Metropolis Many men who have worked there all their lives, are unable properly to gild a common picture frame, though they get employment, and give satisfaction. It is however hoped a better judgement will be formed from the instructions here given, from which it has been known, that a person bred a cabinetmaker, who never before saw gilding, has accomplished the work in the best style in the course of six months.

Of about 150 persons, who call themselves carvers and gilders, the greater number are gilders only; they live in private streets, and make no shew of their work.

BURNISHED GILDING ON WOOD.

To begin with picture frames or mouldings, which are the simplest. In an earthen pan that will hold a quart, take three half pints of strong size, make it very hot, but do not let it boil; add some of the best whiting powdered fine, mix them with a brush, kept for the purpose, or beat them with a piece of lath as an egg is beaten, till they become thoroughly incorporated, and of the consistency of thick cream; put a little of this mixture, with an equal quantity of strong size, into a smaller pan, heat it till nearly boiling, and with a stiff brush, lay it over, the whole work, in order to clean away any dirt, grease, or hand marks; this is called thin whitening the work, and makes a ground for the other operations. When the wood is very dirty, it is absolutely necessary, to wash it all over with a spunge and hot water, before the thin white is applied, which precaution will prevent the chipping up of the preparation. When burnished, the coat of thin white should be particularly well dried; after which the work is to receive four more coats of that which was made of the consistency of cream warmed, but not made so hot, as for their whitening, taking care that one coat is dry before another is applied. Here it is necessary to observe that, throughout this process, one coat must be dry before another is laid on, whatever may be the composition used. The sixth coat, which is also of thick white, must be laid on by passing the brush in a smooth, even, and flowing manner, over two feet of the work at a time, in order to gain a surface and facilitate the smoothing, hereafter to be described. Before the whitening is dry, the flat parts should be rubbed down with a chisel, the hollows with a gouge, and the rounds with the finger, or fingers, as most convenient; should the hollows be too large for a gouge, the finger will answer every purpose. When dry, any superfluous whitening that may have fallen over the edges of the mouldings &c. may be slightly pared off with a chisel or a gouge, according as the parts are situated; then give it a seventh coat, similar to the preceding, and it will be ready for smoothing, which should be performed in the following manner.

Take some close grained pumice stone, and with a sash saw, (an old one will answer the purpose,) cut it into pieces about three or four inches long; (if the work be very small, an inch or inch and half will do) fit them to the different mouldings, using a rasp to form the rounds, and a gouge the hollows. The flats are to be made by rubbing a piece of the pumice on a smooth stone, making the sides at right angles, that it may smooth two sides at a time. During these operations, the pumice must be frequently dipped in water. Lay the pieces thus prepared, in a large earthen pan full of water, not less than two quarts, take a hogs hair brush and a spunge, both of convenient sizes, dip the brush in the water, and wet about two feet of the work at a time, taking the mouldings alternately; then, with the pumice already fitted, rub up and down till a smooth surface is obtained, remove the water with the brush, and squeeze it into the pan, what remains, may be taken off with the sponge

which

which will complete the smoothing of that piece.

Proceed in the same manner, with similar portions, for if too much be wetted at a time, the whitening becomes soft and unfit to bear the pumice stone; the frames must then be set aside to dry. In carved work, the operation of whitening and smoothing, differs somewhat from the preceding. After the thin white is dry, the coats that follow must be rather weaker, and not so thick, as for frames or mouldings: they are to be laid on by carrying the brush over the work, in an even and smooth, but not flowing manner. To smooth, or produce the surface that is required, pieces of lime-wood, or fir, soaked in water. instead of pumice, are used, shaped round, flat, or angular, as may be found necessary, occasionally wrapping round them strips of coarse linen cloth. In smoothing, care must be taken not to rub off too much of the whitening, or the gilding will look poor, and prevent the burnishing of those parts thereby brought too near the wood. The drying may be hastened in summer by the sun, in winter by placing before the fire, not too near, or the whitening will chip. Mix a little strong size, with four times as much water, in a half pint earthen pan; these proportions should be adapted so as to make it three parts full, add a quantity twice the size of a large wall-nut, and half as much prepared yellow stone ochre, mix them well together, with a brush, and coat the work once over, when dry, rub it slightly with glass paper, half worn out; to improve the surface, and proceed to mix and lay on the gold size. In another half pint earthen pan, half full of clear size, mix a quantity of burnished gold size, twice as big as a large wall-nut, with which, coat the work twice over. When dry, burnish the parts intended to be matted with a burnishing stone, and then give it another coat of the same gold size. it must now be reduced by adding to it about two tea-spoons full of water, and as much gold size as you can take upon the point of a knife, coat those parts only, that are intended to be burnished, and here it must be observed, that in laying gold size on carved work after it is yellowed, those parts should be missed, that are too small to to receive the gold even from the smallest pencil, such as the small eyes of foliage &c. to which, effect must afterwards be given, with high coloured or-molu. And proceed to lay on the gold with a cushion, knife and tip, as will be described in oil gilding; but in burnish gilding, Camels-hair pencils must be used for the small parts, and swanquill pencils for the large, dipped in clear water, to wet the work as fast as the gold can be laid on. The hollows and flats must be gilt first, and perfectly dry before the other parts can be proceeded with, when the work is all gilt and dry, burnish the parts intended. And should there be any faults, which can only arise from not being carefully wetted, or from grease those parts must be rubbed off to the whitening, with linen wrapt round the finger, when they are dry they must be gold sized, gilt and burnished. Then reduce a little clear size with hot water, so that when cold, it will merely set, this being the weakest size used in burnish gilding, much care should be taken, that it is not too strong, or it will shew all the joints of the gold. When dry, lay on a coat of this, and when completely dry, rub it over with cotton. In double gilding, which is the best style, the matted parts should be again gilt, using water to wet as before, after which, coat them a fresh with the weak size, use the cotton, and if faults appear, treat them as will be directed in oil gilding, not to stand in the weather. After the faults are all covered, give another coat of the weak size, use the cotton, and then give one of clear size, to keep the gold firm, a coat of or-molu, completes the process. Observe swan quills and camels hair pencils, only, are used after the gold is laid on, and care must be taken in sizing the matted parts, not to touch those that are burnished, which cannot be improved after the burnishing stone.

If it be necessary to embellish the frames or work to be gilt in burnish gold, with composition, it may be had in London, soft from the press, and can be put on after the smoothing, with a little hot thick whitening, or weak glue. What is squeezed out round the edges in pressing it close, may be taken off with a brush and cold water, it must then have a coat of thin white, to remove any grease, and be finished like the rest of work. The composition may also be put on oil-gold work that is not to stand in the weather, but does not require the thin white, and must be finished in the manner of oil gilding; composition is easily moistened when dry, by wrapping it in a wet linen cloth, for twenty four hours.

OIL GILDING TO STAND IN THE WEATHER.

The object to be gilt, whether metal, stone, or wood, must be coated three times over with a mixture of linseed oil, white lead, and a small quantity of spirits of turpentine, if it be wood, it should be previously rubbed with glass-paper, or fish-skin. When the last coat is dry, the work should be gold-sized; take any quantity of gold-size, and with a common hog's hair brush, kept in water for the purpose, mix it with boiled linseed oil till it is so thin that when a little of it be laid on the work to be gilt, the white paint before put on, will appear through, though it must not be made so thin as to lose the tinge of the yellow ochre, then proceed to lay it on sparingly, with fine hogs-hair brushes, proportioned to the parts of the work, when the gold size is good, it will dry in twelve hours, if laid on in the evening, it will be fit for gilding the next morning. Sometimes in winter, and when the gold-size is fresh made, it will take two or three days; to prevent this, an expedient may be used, unknown to the generality of Gilders, to mix with it a small quantity

quantity of Japaners gold size, which will hasten the drying, but in this instance, when it begins to have the tack, hereafter to be explained, it dries very quickly, therefore, great care should be taken to get the gold on as fast as possible. In order to ascertain its fitness for receiving the gold, the work must be touched with the finger, if it feel somewhat adhesive or clammy, but not so as to be brought off by the finger, it has the *tack*, or in other words, is in a fit state for gilding: but if it be so clammy as to come off on being touched, or have any inclination thereto, it is not sufficiently dry, if it have no sucking quality, it is too dry, and must be sized over again before it can be gilt. In laying on the gold, a tip is used which must be previously rubbed with a little tallow grease to make it hold, but it must be so little as to shew no appearance. When the surface to be gilt, whether round, hollow, or flat, is sufficiently large and plain to contain whole leaves, they may be taken from the book, which must he held in the left hand, by the part that is sewed, the leaves of it turned carefully over, and kept always so steady, that the gold may be undisturbed, and lie perfectly flat, take the jip in the right hand, touch the leaf of gold about half an inch deep, on the side opposite the sewing of the book, both hands must then be moved to the place meant to be gilt. Having laid the edge of the leaf already attached to the tip, upon the work, which is always considered as having the *tack*, it will be caught and held fast by the gold size, and the tip will be left at liberty; the book must be slowly drawn away, followed as it moves by the tip which is now used gently to press the gold close to the work, until the whole leaf is on, which must be repeated until those parts large enough to receive a leaf, are all gilt. This method is in use with a few of the best gilders, and may be acquired in an hours practice. For those parts that are too small for the entire leaf, it is necessary to use a cushion, upon which about half a book of gold may be blown out, one leaf at a time, each one carefully turned until it lies nearly flat, when by puffing as near as possible on the centre, it will become smooth and even, and must be cut in strips, with a knife used for the purpose, according to the widths of the different members and mouldings, and then laid on with the tip. As the work advances, or when it is gilt all over, it must be pressed close with a bit of unspun cotton, then brushed over with a dry, soft, hogs-hair brush, one previously used a little in the whitening, will best answer the purpose, in order to clear away any loose particles of the gold leaf. If any defective parts appear, those which cannot be mended by pressing upon them the loose gold just brushed off, which may be done with the brush in hand, or a bit of cotton must be covered in the following manner. Cut a leaf of gold into small square pieces, proportioned to the defects, and with the camel's hair pencil slightly moistening the tip of it, by putting it to the lip, place a piece on each faulty part, which must be again pressed with the cotton. The work is then finished unless the faulty parts are too dry to receive the gold; when they must be again gold sized and gilt, as before directed. In general, boys do not acquire the method of using the gold on the cushion, in less than three months, though a person determined to accomplish it, may do so in one week.

Picture frames, and other work in "oil gilding, that is *not* to be exposed to the weather," to be well done, must be prepared as far as smoothing, in the same way as work to be gilt in burnished gold. When smooth, and after being rubbed with glass paper, it must be coated twice over with size, ratner weaker than that used for whitening, that which is stale answers best. The gold size must be laid on as before directed in oil gilding, and when the work is gilt, pressed with the cotton, and brushed over. If faults appear, they must be treated thus; take a little weak size, as directed in burnish gilding, coat the work all over when dry, wet each part where a fault appears with clear water, and lay on it a piece of gold, with a camel's hair pencil, as before described. This is not to be pressed with the cotton, but gently rubbed with it when compleatly dry, which it will be in half an hour, (as will all the coats that are used for gilding, except oil gold size,) give the work another coat of the weak size, then one of clear size which completes the gilding, but the effect is considerably heightened with a coat of or-molu, such as is used to finish the matted part of the burnished gilding.

TO MAKE STRONG SIZE.

Take a clean saucepan of any size most convenient, fill it nearly with water, when heated as much as the hand can bear, keep putting in cuttings of parchment which best answer the purpose, or glovers white leather shreds, pressing them down well with the hand, till they are within an inch and half of the surface of the water, boil them slowly for one hour and a half, and the strong size will be made; pass it through a hair sieve into a pan, and set it aside for use, the same parchment or shreds, will again yield the same quantity of size, stale size stinks and is unfit for use.

Clear size, differs only from the preceding, in these particulars, it must be made in smaller quantities; the parchment or shreds must be washed in several waters milk warm, till no dirt appears, it should boil only fifteen minutes; be passed through a finer sieve and when reduced care must be taken that the water is perfectly clean.

TO MAKE GOLD SIZE FOR BURNISHED GILDING.

Take one pound of pipe clay, put it into an earthen pan full of water, when soaked, pour off the water and

and grind it on a stone, with a muller, such as is used by house painters; now and then sprinkling it with water as it becomes dry; care must be taken that no dirt or grease be on the stone or muller, and as it is ground, put it into another pan; then take half an ounce of the best black lead, the eighth of an ounce of mutton suet, pound them together with the muller, and then proceed to grind them particularly well, using water as before directed for the pipe clay, when ground, put them into a smaller pan; grind half an ounce of the best red chalk, and mix the black lead, suet and chalk well together, on the stone, with a pallet knife, and add to them the clay, until these ingredients are thoroughly mixed, put them into a covered earthen pan to prevent dust or dirt, to be used as wanted. Ten or twenty pounds may be made at a time. The gold size must be moistened once a month or oftener with clean water to prevent it from getting dry, in which case it would be necessary to grind it again. Care should be taken in selecting these ingredients; the best black lead dust from the saw of the pencilmakers, is most fit for the purpose, it may be had for *7d.* the pound at any respectable shop in that line, while the best black lead in the lump sells at from two to four guineas per pound. In choosing the clay take that which has the least grit, it may be discovered by putting a little into the mouth, the darkest is generally the best, of which the greatest choice is to be had at the pipemakers. The softest red chalk, such as is used for drawing must be chosen, though the gold size may be very well made without any, as its principal use is to heighten the colour of the gold when burnished.

PREPARED PIPE CLAY AND YELLOW STONE OCHRE.

The pipe clay must be chosen and ground, as directed in making gold size, then laid by for use in a covered earthen pan, and occasionally moistened as the gold size. The stone ochre must be of the best quality, and prepared in the same manner.

TO MAKE OR-MOLU.

In half a pint of clear water, gently boil two ounces of the best gamboge powdered fine, for five minutes, strain it through a linen cloth, put it into a corked bottle.

Take one ounce of saffron, half an ounce of turmeric, and one quarter of an ounce of dragons blood, boil them in one pint of clear water, for fifteen minutes, now and then stirring them from the bottom, strain them also through a linen cloth, and put them into a corked bottle.

Put about five or six nobs of starch into a clean half pint earthen pan, make them into a paste, with a teaspoon-full of clean water, using the finger, then add water till the pan is three parts full, boil it for one minute, and it will be clear like clear size, blow off skin that will arise from the boiling, and put it immediately into another pan, add four drops of the gamboge liquor, two drops of the repass, stir them round, and the or-molu is made and fit for use. The eyes of foliage &c. in carved work, must be touched with a little of the gamboge liquor, called high coloured or-molu, unmixed with any thing else.

The or-mulu in general use though it is by no means the best, is made by dissolving the gamboge in spirits of wine, instead of water, which will give it the appearance of clear varnish; but when dropped into clear size to be substituted in this case for starch, it will be yellow; the quantities of the ingredients are alike in both cases.

Plaster figures, vases, busts, &c. are gilt both in burnished gold and oil gilding, by coating them, first, with very hot weak size, and afterwards four times over with hot clear size, if any holes appear, they must be evenly filled up with putty, made of strong size and whiting; the rest of the process is the same as after *smoothing* in both cases.

To gild paper in burnished gold, it must be tacked to a board by each corner, gold sized and gilt, it must be burnished on a piece of plate glass, bedded in putty, or on a clean marble flag.

TO MAKE OIL GOLD SIZE.

Put as much linseed oil into a broad earthen vessel as will cover the bottom an inch deep, and add to it as much water, four or five inches, let the vessel containing this, be exposed to the weather for three or four weeks, occasionally stirring it till the oil appears of the consistency of treacle, it must then be separated from the water, put into a long bottle, or separating funnel used by the chemists, and placed in such a degree of heat as will render it perfectly fluid, the clear part should then be poured off, and it will be fit for use; take any quantity of the best yellow stone ochre, and a fourth part of white lead, mix them with the oil on a flag, using a muller and pallet knife, this mixture is oil gold size, it must be put into an earthen vessel, and covered with water, to prevent it from skinning.

This gold size is very troublesome to make, and may be bought in its highest perfection, which is six or seven years old, at Norgroves or his successors in Oxford-street, corner of Swallows-street, from whence it can be sent to any part of the Kingdom.

BRONZING ON WOOD.

The preparation for it is entirely the same as for gilding, until the work is smoothed, when it must be coated with a mixture of clear size and lampblack.—Grind separately with water on a stone with a muller, the following ingredients; Prussian blue, patent yellow, raw umber, lamp-black and pipe clay. Take a small pan three parts full of size, not quite as strong as that which is denominated, clear size in gilding

gilding, add such quantities of the ingredients as will make a good colour, (half as much more of the pipe clay as of the rest is generally found to succeed,) this, however, must be directed by fancy, as the appearance of real bronze is of various colours, give the work a coat with this mixture, when dry, another, and proceed to lay on the bronze, which is sold at most of the colour shops; with a fine hogs hair brush, the tip as slightly as possible, moistened in water, take up a small quantity of the bronze powder, which lay upon the colour, when dry, the work must be burnished all over, taking care not to chip it up, or the whole of the operation must be repeated for the chipped parts. After burnishing, take a little castile soap, make a lather rather thin, and with it coat the work all over, to take off the glare of the burnish, finish by rubbing it carefully over with a piece of woollen cloth; the appearance of gangreen which belongs to the cavities, is made by slightly wetting them with a small camels hair pencil, dipped in the lather, over which a little dust of verditer gum must be shaken: when dry, what is superfluous, may be brushed off with a hogs hair tool.

END OF CARVING AND GILDING.

COACH-MAKING.

The coach maker manufactures coaches and chaises of all kinds, which are, of course, as various in their constructions as they are in name. The limits of our work will not allow us to enter very extensively into this subject; we shall, however, say enough to give the mechanic and the gentleman an adequate idea of the structure of the more common kinds of carriages; referring our readers to Mr. Felton's *Treatise on Carriages* &c. in three volumes octavo, for more particular and minute details. To this work we readily acknowledge our obligations for much valuable information, in the practical part of the business of coach making.

A coach has been defined, "a convenient carriage suspended on springs, and moving on four wheels" intended originally for the conveyance of persons in the upper circles of society, but now become very common among the middling classes, in almost all civilized countries. In London, there are 1,100 hackney coaches constantly employed for the conveyance of its inhabitants from one place to another. In Bristol, in Liverpool, and in Bermingham, and perhaps in other large towns: coaches of the same kind are used for the same purposes. The fashions with regard to the form and ornament of coaches and other carriages for pleasure, are perpetually changing; the chief kinds now in use, are the close coach and chariot, the landau, which can lower its roof, and part of its sides, like the head of a phœton; the barouche, or open summer carriage, made on the lightest construction, the chariot which is intended only for two or three persons; the landaulet, or chariot whose head unfolds back; the phœton and caravan, which have only a head and no windows, with a leathern apron, arising from the footboard to the waist. These all run upon four wheels. Of the two-wheeled vehicles, there is the curricle drawn by two horses, each bearing on a narrow saddle, the end of a sliding-bar or yoke that upholds a central pole; the gig, chaise, or wiskey that have each only one horse, which moves between a pair of shafts, borne nearly horizontally, by means of a leathern sling passing over the saddle tree. When a gig &c. has two horses, one preceding the other in harness, the machine and its horses are taken together, denominated a *Tandem*, a latin word signifying at length.

The art of coach making, has, within the last fifty or sixty years, been carried to a very high degree of perfection, with respect to the strength and elegance of the several sorts of machines included in that branch of manufacture. Coach, and coach harness makers, though professions of a different nature, are priveleged by each other, to follow either or both trades. The coach maker is generally understood to be the principal in the business, being the person who makes the wood-work. There are however, but very few professions, in which a greater number of artisans are necessarily employed, such as wheelwrights, smiths, painters, carvers and gilders, curriers, lacemakers, woollen cloth manufacturers, and many others.

It is an invariable rule, that carriages of every kind should be adapted, not only to their different uses, but also to the different places for which they are intended. A coach that is the best possible for the paved streets of London and other large towns, is not the most proper for country use, and one that is adapted to the excellent roads of England, would not be fit for many parts of the Continent. The construction of every carriage should be as light as the nature of the place it is destined for, and its necessary work will admit; superior strength, can only be effected by addition in the weight of materials, which a regard to the horses, will make a person very careful not unnecessarily to increase. The great art then consists in building as light as possible, yet so as sufficiently to secure the carriage from danger; what a light carriage may lose, by wearing a shorter time, than one much heavier, is more than compensated by the preservation of the cattle.

The form of the structure of a carriage depends much on fancy; the size is proportioned to the intention of its use, and regulated by the width of the seat and the height of the roof; the timbers of a carriage body should be of dry ash, and formed with great exactness; the pannels are made of soft straight grained mahogany, smoothed to a fine surface, and fitted or fixed in prepared grooves, or bradded on the surfaces of the framing, the insides are to be well secured by gluing, blocking and canvas, to the pannels, the roof and lining or inner parts are made of deal boards.

As no parts of the framing of the body, if well executed are likely to fail by use, a reparation in consequence of accidents is all that is to be expected. The pannels generally suffer most injury, either from

from excessive heat, or from the bad quality of the timber; of course, great attention is required in selecting good boards for this article, which if not very dry and well seasoned, are sure to fail by drawing from the grooves, bulging or cracking. Even though the timbers are good, if the carriage is exposed to any excess of hot weather, it is a great chance but they will fly: but no discredit ought to attach to the builder from that circumstance.

The first summer a carriage is used will prove the sufficiency of the pannels. So soon as they begin to start from the grooves, as they mostly will, in some degree, the builder should examine, and relieve them where confined, to prevent cracking. A little drawing from the grooves is to be expected, and is of no material consequence: but if they crack, it will be a disagreeable object to the eye.

As sufficient room in the carriage makes the seats comfortable, its capacity should be the first object, and the width of the body ought to be in proportion to the number it is meant to accommodate. Open bodies have this advantage, that three can sit with tolerable ease on the same length of seat, as would accommodate two in a confined one. A full sized seat for a close body to contain three persons, is about four feet one or two inches; that of an open body, three feet five or six inches. This latter size is sufficient for two persons in a close carriage, but a seat of from two feet seven inches, to two feet eight or ten inches, is sufficient in the open bodies.

The width across the seats is never regular, but is adapted to the shape of the body. The usual width is from 14 to 18 inches. The height of the seat from the bottom, is in general 14 inches, and from the seat upward to the roof, from 3 feet 6 inches to 3 feet 9 inches without the cushion.

It frequently becomes convenient to make the seat moveable, which is sometimes necessary to give freedom to extraordinary head dresses. Few people rise above 3 feet from the seat, so that allowing two inches for the cushions, there is left in the clear, without the head dress, from four to seven inches.

The bodies of a post chaise and chariot do not differ from each other, but the purposes for which they are intended, alter their name. The chariot is distinguished from the post chaise, by the addition of a coach box to the carriage part. The post chaise being intended for road work, and the chariot generally for town use. The materials of carriages meant for post work only, are somewhat lighter than those of a town carriage; but when alternately used the strength must be sufficient for either. The framings are not required to be so strong for one or two, as for three persons. If a carriage is generally used for three, the length of the seat should be from four feet, to four feet one or two inches, but if only for a third person, occasionally, three feet eight inches will be sufficient, with a seat to draw out from the centre. A greater width is usually allowed at the front, than at the back of the seat, to render it more commodious for the elbows. The door lights or windows, are frequently contracted on the seat side, that the passengers may be more secure from outward observation, while at the same time, there is a sufficient view from within. The following is a description of a body complete in all its parts, as given by Mr. Felton. The upper parts, except the roofs, are generally called upper quarters, that is, side and back quarters. The usual mode of finishing these, is by filling the vacancy with deal boardings, firmly battened on the inside, and covering the surface with leather, tightly strained on, and nailed at the inside edges; over which a moulding goes, and is sewed at the outside edges, making a welt, or is nailed in a prepared rabbet, and covered also with mouldings. Other quarters have the vacancy, the pillars, and rails, covered with a pannel or mahogany board, finely smoothed on the outside. The leathered surface is the most secure; the pannel surface looks the best; but the brads, with which they are confined, and the other nailings of the head-plates, mouldings, &c. occasion them frequently to split.

"The sword-case is prepared in the same manner as the quarters, either with a leather or mahogany surface.

"As the present is an improved method of putting in the lower side pannels in a rounded form, they are thus represented It adds considerably to the fullness of the side, and exhibits the painting thereon to a much greater advantage; this is done by the door and standing pillars being left full on the outsides, and reduced by rounding them towards the bottom.

"The inside work, where the glasses are contained in the front and doors, is only lined or cased with the boardings, and nailed in rabbets on those pillars which form the lights or windows; the other inside work is battening, blocking, and gluing of canvas, along the edges, and across the grain of the pannels, which gluing very much preserves and strengthens them. The blocking is also a material assistance to the strength, which is done by a half-square, cut across, or angle-ways, cutting it also in short lengths, and gluing the square sides against the pannel and its framing.

"The battens are long, thin pieces of board, placed across the grain of the wood, bradded, or secured by blocks, or canvass, in order to strengthen or support those parts to which they are applied.

The inside work, after being thus finished, should be immediately painted all over, except the seats, and in particular the door and front pannels, before the lining-boards are fixed in, so as to expose no timber to the air uncovered with paint, as the air materially effects it, particularly the wide boards, or pannels, as they swell in wet, and shrink in dry seasons;

seasons: a proper attention, in this particular, is indispensably necessary."

The accommodation of a coach body makas it convenient for large families, being for the most part capable of holding six persons accasionally; but as the size of the body affects the weight of the whole machine, the builder has only to proportion it to the number it is intended to contain. The difference of this from the chariot already described, is only in the length, for the addition of a seat side, and every part of the framing bears the same name in both carriages, but it may be observed that the coach has no fore pillar like the chariot, because it has no windows in front.

The bodies of the landau and landaulet, differ nothing in shape from those already mentioned. The landau is of the coach, the landaulet of the chariot form. The weight of these is so much greater than that of the carriages in their simple structure, that they are now but seldom used. The difference, however, excepting additional strength of timber, is only from the middle rails upward, to which height the doors open. It is usual to add a spring bolt on that side of the door, which shuts to prevent its being opened when either the glass or shutter is up.

In open carriages, as phætons, curricles &c. there is a great variety of forms, therefore no general rule can be observed in building them, but they are mostly fastened according to the fancy of their owner. Those intended for single horses, are for the most part light, the length of the seat is generally adapted for two persons only, those for two horses, are made of stronger timbers and are more roomy.

The method of hanging the bodies depends also on fancy, or a conception of ease; and some bodies are not hung at all, but fixed on the shaft of the carriage, depending entirely for their ease on the springs which are fixed underneath, and which support the shafts on the axletree.

The heads to some open bodies are permanently fixed, and others are made to take off, but the addition of their weight and their great expence, frequently render their use objectionable.

The gig body is principally used in a curricle, or handsome chaise carriage. The hind loops which suspend the weight, are fixed through the corner pillars. The method of hanging at the fore part varies according to the taste and judgment of the builder, or the situation of the body. The side pannels may fill the space between the two pillars, but in conformity to the present mode of building, the side is divided at the standing pillar, by a door, or an imitation thereof, preserving the same shape. In either case, whether a sham, or real door, it projects above the surface of the pannels. The size of the body varies according to the purposes for which it is intended, but in general, the measure is from 2 feet 10 inches, to 3 feet 2 inches on the seat.

Though the word four wheeled carriage usually implies a carriage complete, yet it is distinguished among builders, as the under part only, or frame with the wheels, on which the body is placed. It is the carriage which bears the stress of the whole machine, and of course, every thing depends on its strength. It should be well proportioned, according to the weight it is meant to support, always allowing rather an over than under proportion, to avoid the risk of accidents. A proper application of the iron work to support the pressure, is a thing materially to be attended to, and great care should be taken that there are no flaws in it. The timbers which are of ash, should be of young trees, of the strongest kind, free from knots, and perfectly seasoned before they are used, and as many parts of the framing are obliged to be curved, it is best to select such timbers as are grown as nearly as possible to the shape. The workmanship must be strong and firm, and not partially strained in any of its parts, as it is liable to much racking in its use. The timbers throughout, are lessened or reduced for the sake of external appearance, which appearance is assisted also with moulding edges and carving.

All four wheel carriages are divided into two parts; the upper and under carriage. The upper is the main one on which the body is hung, the under carriage is the conductor, and turns by means of a lever, called the pole, acting on a centre pin, called the perch bolt. The hind wheels belong to the upper part, the fore wheels to the under.

Of four wheel carriages there are two sorts, the perch and crane neck, in which there is a material difference in the building and properties, but this does not effect the bodies, as they will hang equally well on either. The perch carriage is of the most simple construction, and lighter than the crane neck, and as the width of the streets in London, gives every advantage to their use in turning, they are the most general. The crane neck carriage has by much the superiority for convenience and elegance, and every grand or state equipage, is of this construction; but the weight of the cranes, and the additional strength of materials necessary for the support, make carriages of this sort considerably heavier than the other.

The track in which the wheels of every carriage are to run, is generally the same, except when intended for particular roads, in which waggons and other heavy carriages are principally used; these leave deep ruts, in which light carriages must likewise go, or be liable to accident. All four wheel carriages should have the hind and fore wheels to roll in the same track, the ordinary width of the wheels is four feet eight or ten inches, that of waggons or carts, generally measure more than five feet, to which chaise wheels, (being principally intended for the country,) are adapted. It is immaterial to what

what width wheels are set, if used for running upon stones, but upon soft and marshy roads if exactnes, is not attended to, the draught is considerably increased. The different heights of the hind and fore wheels, make also a difference in the length of their axletrees, agreeably to the proportion they bear to each other, the fore wheel has the longest axletree by one or two inches between the shoulders.

The length of the carriage is regulated by the size or length of the body which it is intended to carry; but it always takes its measure from the centres of the hind and fore axletrees. In general, a perch formed carriage, measures nine feet two inches for a chariot, and nine feet eight inches for a coach, but in a crane-neck carriage, on account of the bow for the wheels to pass under the measure, in a chariot, is nine feet six inches, in a coach ten feet.

We shall now give a more particular account of the perch as described by Mr. Felton; and afterwards explain the nature of Mr. Edward Stracey's invention for an improved method of hanging the bodies, and of constructing the perches of four wheeled carriages, by which he says, such carriages are less liable to be overturned, and for which invention he obtained some years since his majesty's letters patent.

"The perch is the main timber of the carriage, which extends through the hind and fore spring transom or bars. By it the principal part of the upper carriage is supported. The hind part is supported, and united to it, by means of hooping two extending timbers, called wings, on the side. The fore end is fixed or united to the perch by means of a strong piece, hooped at the top, and framed through the fore transom, called a hooping piece; but some carriages have a horizontal wheel in the front, the same as the crane-neck carriages; and these have no hooping piece to the perch, but are secured by means of side-plates. Those on the general principle have, at the bottom in front, a flat piece, left extended, called a tongue, which goes through a large mortice in the fore axletree bed, and through which the perch-bolt passes; its use is to keep the fore axletree bed steady in its place.

"Sometimes the perch is made of a bent form, called a compass perch, for the purpose of admitting the body to hang low, or to form a more agreeable line to the shape thereof; those perches are of a very ancient form, but are now revived with considerable improvement from their original shape, and are become the prevailing fashion When the carriage is intended for a whole or horizontal wheel, the perch has no hooping-piece, but is bolted by the plates at each end to the inside of the transoms.

"Plating with iron the sides of perches is a great improvement, and is now most generally done, and always must be, to those compass perches, if required to be light in their appearance, as the size of the timber is so much reduced by cutting them to this shape.

"To the straight or compass perch, iron plating on the sides is a great addition, as it will admit the timbers to be so much reduced, that a sufficient strength is preserved, though but half the usual size; the plates, as fixed edge-ways to the sides of the perch, will support ten times more weight than if flat-ways on the bottom, which is the method of plating a perch in the plain or common way; and many of those carriages which are made up for sale, have even the bottom plate omitted; but the certain consequence of this superficial method is, the sinking or settling of the perch, whereby the carriage is contracted quite out of its form, to the great injury of it, both for use and appearance, and there is no remedy but by a new one."

Mr. Stracey's invention embraces four objects 1. The constructing of the perch of a four-wheeled carriage, in such a manner, that either of the axletrees may have a vertical motion independent of the other; so that the axletrees may be in different planes at the same time. 2. The hanging of the body on the springs of such a carriage, in such a manner as will tend not only to diminish the liability of its being overturned, but add also to the ease of its motion. 3. The forming a collar-brace, which shall almost immediately bring the body to an equilibrium, should the centre of gravity be moved. 4. The forming a perch-bolt, by the use of which the carriage may be more easily turned to the right or left, and the friction that now takes place, by the use of the common perch-bolts between the wheel plates, the transom bed, and the fore axletree bed reduced almost to nothing.

Carriages constructed on this principle, differ but little in appearance from other four-wheel carriages; the chief distinction lying in the construction of the perch, and its having a revolving motion, and in the hanging of the body on the springs. The perch being allowed to turn on its axis, the fore axletree bed may have any degree of obliquity required, provided the body is not hung on the carriage, without affecting the horizontality of the hind axletree bed, and *vice versa;* and it is by the instrumentality of this motion, co-operating with the mode of hanging the body on the springs, and by the aid of collar-braces, that the body of the carriage may be kept nearly on the true level, or at least sufficiently so to prevent its being overturned, although either the fore or the hind axletree may have a great degree of obliquity from the plane of the horizon. A similar effect and security may be obtained by inverting the construction of the perch, and by having the fixed part of the perch in the hind axletree bed, and the revolving part in the transom bed in front; or by making the perch revolve on an axis at each end, or by any other mode which will allow the hind and fore axletree beds, when connected by means of a perch, to be in different planes at one and the same time, as by permitting one axletree bed, provided that the body is not hung on the carriage, to remain

main parallel to the plane of the horizon, and by making the other stand perpendicular to it.

The principal variation of this invention, from the common method of hanging the body on its springs, consists in the body-loops, which must be so extended, that the ends of them may come nearly under the shackles of their respective springs, and each of them so formed, as to end in a cylindrical axis of one to two inches or more in length, and of sufficient strength to support the body; and on each of these body-loop axes, a shackle, for the reception of one of the mainbraces, should be fitted, ending in a cylindrical box or rocket, made so as to work and turn on the axis of the body-loop, and secured to it by a nut and pin; and the connection between these shackles and their respective boxes should be by means of a strong joint, working towards the front and hind part of the carriage in the direction of the perch. The body is to be hung by the main braces, attached to these shackles on the springs, in the same manner as other carriage-bodies are usually hung. When the body is this hung, the action is as follows; should either of the hind or fore wheels descend into a low spot in the road, or ascend a raised surface, the boxes or sockets on the body loops will turn on their axes, and keep the whole on a proper equilibrium, so as not to be overturned.

Another part of the invention is the application of a cylinder to the collar-braces of carriages, by means of which, should the centre of gravity of the body of the carriage be moved by any inequalities in the road or otherwise, either to the right or left, the equilibrium will be almost immediately restored by the motion of the cylinder, or roller on its axis, and the consequent lapping and unlapping of the straps; for to whichever side the body is impelled, on that side will the collar brace be lengthened, and of course the opposite collar brace proportionally shortened; one side is made to operate as a check upon the other, in order to bring the body to its true centre.

The last part of the invention is the perch-bolt, which being properly placed, the fore axletree bed may be turned either to the right or the left, with much greater ease than if the common perch-bolt were made use of, the usual friction between the beds and wheel-plates, being almost wholly removed from their being gradually separated by the lifting of the screw, in the act of turning.—*See Repertory, New Series* Vol. XIV.

The timbers of the crane neck carriage, are of the same description as those of the last, excepting the perch and hooping-timbers, which are not used. The hind and fore ends are fixed to the cranes, which makes the bearings more steady than those of a perch carriage. The whole will be better understood by the following description.

Figure 1, of plate is an elevation of a crane-necked soach complete, *Figure* 2, is a front view of it, shewing the fore wheels and under carriage; and *Figure* 3, is the horizontal plan of the same, many parts of this are too evident and universally known to require any reference, as the wheels, the body, the coach box, the boot, the springs &c. A a, are the two cranes which are made of iron, and answer in their use, to the wooden perch of the common carriage, which is the main timber of the carriage, extending and connecting the hind and fore spring transom D D, and E E, or cross-bars which support the springs F F and G G, and thus forming one frame called the upper carriage, in which the body is suspended.

The two iron cranes a a, form the same connection, but in a more complete manner, and they have a bend or neck at b, which admits the fore wheels to pass under them when the carriage is turned short about; the cranes are united to the fore carriage, by being screwed fast into the fore spring transom D, and they are farther screwed by clipping them down to a cross timber near A, in *Figure* 1, and marked B in *Figure* 3, it is called the budget bar, from the circumstance of its bearing the boot or budget, and it has two pieces A A, called nunters framed into it, which connect it with the fore transom D, these pieces make a platform or frame, on which the budget immediately rests; the springs F, are bolted to the transom, at the lower end, and have an iron brace F *Figure* 1, called the spring stay.

The fore transom, or fore spring bar D, is the most essential part of the cross framing, it is a strong timber to which the cranes are fixed, by passing through it as before mentioned, therefore, an under carriage is attached thereto, by means of a large, round, iron pin d, *Figure* 3, which passes through its centre, on the bottom is a thick, flat plate, made flush to the edges, called the transom plate, on the ends the springs are fixed, and on the top the boot or the blocks that support it, are rested.—E, is the hind transom, or hind spring bar, something similar in its use to the fore transom, but not required to be of such strength, to this the ends of the cranes are fastened, and the timbers called nunters, which run parallel with them, are framed into it, and unite it with the hind axle bed H, on the ends the springs G G, are fixed; the blocks or pump handles I I, are placed on the top to support the foot board K, or platform, and the footman's step piece bolted on the outside.

H, is the hind axle-tree bed, it is a strong timber which receives the axle tree, the cranes a a, as before mentioned, are securely fastened to it, and it is connected by two pieces called nunters, as before mentioned, with the bend transom E, the bottom is grooved to receive the axle tree, which groove is called the bedding for the axle tree, but is usually bedded at the ends only. At the two ends of this timbers are left projections called cuttoos, which cover the top or back ends of the wheels, to shelter the

the axle tree arms from the dirt, which would otherwise get in behind the wheels, and clog them.

I I, are the hind blocks, which are called pump handles; when further extended than what is here represented, they are frequently called raisers, as their use is only to heighten the platform from the hind framings, that the appearance may be light, and that the footman may be sufficiently raised, according to the height of the body; they are bolted on to the axletree bed and spring bar E, and to prevent the too heavy appearance, there are often neatly ornamented with carving.

The footboard or platform K, on which the cushion for the servant stands, is a flat thick elm board, bolted on with blocks to which it is also screwed.—L, the boot, a large box made of strong elm board, nailed and screwed together, having a door in the front, which door should be made framed, and boarded, and confined by a bolt and thumb nut; the surface of this boot should always be covered with a rugset, or japanning leather; it is bolted across the transom D, the boot or budget bar B, and fore blocks as shewn in *Figure* 1, and is sometimes raised on side blocks, to lighten the appearance of the fore end of the carriage.—The parts marked M N O P, including the fore wheels, are called the fore or under carriage, united to the upper carriage by the perch bolt.

M, The fore axletree bed, which is required to be a strong piece of timber, in which the fore axletree is bedded; on this the upper carriage rests. In this timber the futchels N N, are fixed, it is also cultoved on the end, the same as the hind bed.

N N, The futchels, are two light timbers, fixed through the fore axletree bed, contracted in the front, to receive the pole O, which part of the futchels is called the chaps; but they widen towards the hind end, on the top of which the horizontal circle P C, is placed with proper blocks to raise it.

Across the fore ends of the chips of N N, the splinter board P, is fixed; the futchels are framed in a slant direction, to give a proper height to the pole; they have iron braces beneath, but sometimes the futchels are framed in a horizontal direction, and are made to rise in a cant from the front of the horizontal wheel, otherwise the pole must be compassed to raise it to a proper height.

P, the splinter bar, is a long timber to which the horses traces are attached; on the ends are sockets, with eyes, in which the wheel irons g, are placed, and extend from thence to the ends of the axletree arms, holding the splinter bar tightly back to oppose the strain of the draught, which is taken from the axletrees at the ends by the wheel irons, and at the middle from the futchels, proper roller bolts h h, being fixed at these situations to receive the traces by which the horses draw.

c c, The horizontal circle called a whole wheel front, it consists of two equal circles, one of which is attached to the under carriage, by bedding it on the fore axle bed M, and the other is fixed beneath the fore transom D, the flat surfaces of these circles apply to each other, and the perch bolt d, is in the centre of both, their use is to preserve a steady bearing for the upper carriage to work upon while turning round, so that in whatever direction the fore carriage may be, the steadiness is always preserved.

O, the pole is a long timber, which occasionally is placed in the futchel chaps N N, being nicely fitted therein, and is confined by two plates, the one bolted to them at the bottom in front, and the other at the top at the back end of the chaps; the security is also assisted by a wooden pin k, called a gib, which is placed across the futchels, and in a staple which is in the pole; and an iron pin also goes through the futchels and the poles at the free end; on each side of the pole the horses are stationed, and strapped to a loop at the fore end, called a pole ring, its use is to conduct the fore carriage, and may probably be called a carriage lever.

k, The pole gib, made flat at the bottom, and rounding at the top, to fit the staple in the pole, which it keeps from using up at the fore end, it is nailed on by a loose strap to the futchels, and kept in its place by another strap nailed on the opposite side, which is hitched on a brass or plated button.

Two-wheeled carriages have the advantage of all others for simplicity and lightness; but in this sort of carriage there is more risk than in those that are four-wheeled. That which makes the variety of this sort of carriage, is the method of placing the bodies, whether hung from springs, or fixed on the carriage, which is decided principally by the wishes of the owner; the generality as we have seen fall under the description of curricles, gigs, wiskies, or chairs; but that in which the principal difference lies, is the curricle, being as has been already noticed, formed for two horses abreast, which at present is one of the most fashionable carriages in use. The gig differs also from the whiskey materially, the whiskey being constructed on the most simple plan, with the body united to the carriage, while the gig exhibits a greater portion of taste, having the body hung in various directions; it is by the form of the carriage, and the method of placing the body, that they are named.

The strength of the carriage is to be regulated by the size of the body which it is meant to support, as also by the places in which it is to be used; as in rough roads an additional strength is required. The timbers are usually of ash; but a preferable method of building, is to make the shafts of a foreign timber, of the West India growth, called lance-wood, which is of sufficient strength, even when reduced to half the size of ash, and is so elastic as to give great ease to the rider, and at the same time always preserve the shape. The draught should in all cases be taken from the splinter bar, which yields to the motion

tion of the horse; and the nearer to the axle the fixtures used to draw by are placed, so as not to be very low from the purchase, the lighter is the draught. The carriage should be so formed, in such a manner, that the axle tree may be placed nearly on an equilibrium; so that when the passengers are in the body, the weight may not exceed 25 or 30 lb. on the back of the horse.

Coach and chariot carriages are built exactly similar to each other; the only difference is the superior strength of the materials.

Phætons have a great similarity to them; but the situation of the springs, which are placed in various directions, makes the appearance the only material difference from other carriages; so that excepting the blocks and budgets, they will be reduced to the same principle as the others.

The workmanship is nearly the same in value to all carriages on the plain system. The materials are reduced in their value for the lesser carriage. The value, when thus far executed, is what is reckoned the first charge or rule to follow; the wheels, the boots, the coach boxes, the raised hind or fore ends, the blocks for the springs, and also the painting, are added afterwards; so that, in whatever manner they are compleated, their value may be ascertained.

The art of carving contributes more effectually than any other part of the work, to the beauty and elegance of a carriage. In common carriages, all that is meant by carving, is the finishing the ends of the timbers with scrolls, and the edges with mouldings. If any carving is bestowed on plain carriages, it is on the blocks or raisers, front views of which are more conspicuous than any other timbers.

On carriages for common use, the more simple and plain the ornaments are, the better, provided a good design is preserved, leaving the painters pencil to effect what is omitted in the carving, which is a tolerable substitute in a common carriage.

Figure 4, is a representation of a gig, to which Mr. Williams's patent preserver are applied. The invention consists of an axle tree having a strong iron spindle of about 9 inches high, firmly fixed, or welded upon it, immediately within each wheel, this spindle carries a preserver, marked A B C D, which consists of two arms or branches of steel A B, spread out somewhat similar to an open pair of compasses, with points turned C and D, round it has a socket at the top, that goes on the spindle, and fixes with a bolt, it is capable of being raised or lowered, according as the road requires it, but having the end C and D, about three inches from the ground, has been found sufficiently high for any road that will admit of a carriage to travel on it.

Another part of this invention consists in fitting the shafts that they can be detached, but when put to, they are connected to the axle tree by the centre, terminating in a hemispherical ball, the flat side resting upon the middle of the axle tree, which ball is strongly pressed down by a hollow cap that fits it, and it is fastened within the body of the gig with an iron rod, so that by pulling this the shafts are released.

These simple contrivances produce the following effects, viz.—Security when the horse falls, because the arm C, of the preserver, supports the weight of the carriage, and prevents it falling on the horse, so that he has an opportunity of recovering himself. If the horse rears up the arm B, the preserver touches the ground, and prevents overthrowing the carriage backwards. If either, or both the wheels break, or come off, the preserver catches the weight of the carriage, and prevents it breaking down, as they also do if the shafts break.

If the horse kicks or runs away, the shafts can be disengaged in an instant, as shewn in *Figure* 4, by pulling the handle of the iron rod, which releases the ball from the axle tree, while the parties sit perfectly safe receiving only a gentle tilt, or recoil of about three inches, until the preserver reaches the ground, and gradually loses its impetus, at a distance of a few feet upon its turned up, or sledge formed end.

From this explanation, it appears, that no springs are required for accomplishing these objects, that repairs will seldom be necessary, and that the cost cannot be much more than that of the ordinary two wheel carriages.

At the first view of this invention, the novelty of the preservers may not reconcile them to the eye; but upon investigating the principles on which the whole is constructed; what appears unsightly gradually becomes ornamental, from a conviction of their indispensible necessity, and the important results. They may however, be made invisible by joints or hinges to fold up, but this mode will be more expensive, and less secure.

This invention also applies with great safety to all four wheel carriages, in the following manner, viz.—By firmly uniting a spindle to the axle, as herein before shewn, but with the arm of the said spindle downwards, and forming the preserver with the brace of the two arms curved at the bottom, which when called into action, operates as a sledge, upon which the carriage can move, and be supported, the same being fixed on the spindle, through the socket, in the reverse way.

We now come to the iron work, of which the articles are extremely numerous, and are manufactured by many different mechanics, such as spring and tyre-smiths, &c. The whole of the iron-work requires to be made of particularly tough metal, and to be fitted with extreme exactness, taking care that each gives its proper support without straining or twisting, and that its substance be adequate to the weight it is meant to carry. The iron-work forms

forms the principal part of the carriage both for value and use; of course its properties cannot be too much attended to, we shall begin with the springs.

The springs of a carriage by which riding is made comfortable, require the greatest attention to their properties, otherwise their effect is materially injured. They should be all manufactured of a well prepared and properly tempered steel. The greater the number of plates there are confined within the hoop the better: and the longer the spring, the more easy and elastic its motion will prove. Those that are the least erect and of course that incline most to the weight which they carry, and that are also the longest, from the bearing, or stays, have superior advantages. Their forms are various according to the purpose for which they are designed: and they take their names according to their shape, such as the S, the C, the French horn, the scroll, the worm, the single and double elbow or grasshopper spring.

The springs support the weight at their extremities, by means of hoops and shackles, and their elasticity is from the hoops at which parts the plates are all made thickest, gradually tapering thinner toward the extremities, and shortening about 4 inches in each plate, from the hoop where the bearing for the spring is fixed. Those that are placed in an erect form are supported with iron stays, which clip the spring at the hoop. Those that are placed horizontally are supported from the middle and play the whole length; and those that are circular, have frequently no stays, but are well secured to the bearings, short light springs that contain few plates, have frequently no hoops, but the plates are confined with a small rivet, and the bolts with which the spring is confined to its bearings.

Figures 6, 7, and 8, represent some of the varieties of springs in use for carriages, *Fig.* 6, called a double spring, is used for a coach or chariot, and has united to it at the back plate an additional spring, which turns the reverse way, to carry separate things, such as the budget, or hind platform; it has a double shackle at g, one link of which carries the body, and the other the boot, or platform.

The reverse spring has only to carry the hind part of the same boot, or platform. The stays and loops marked a, b, c, d, e, f, are for the following purpose, the stay a, is rivetted within the hoop b, and clips at bottom, the fore or hind transom, and is there fixed by this bolt c, and is supported at the hoop by a stay d, which rests on the hind axle tree bed, or budget bar; a stay e, also clips or bolts through the spring at bottom, and clips or unites in a cap with the other; to oppose the pressure, it has a shackle f, bolted loosely on the top, for the weight to hang by, and g, is the shackle for the other spring,

Figure 7, is the scroll spring: this is a peculiar formed spring for ease, and is used to various kinds of carriages, it rests, and is fixed on a long block for phætons, or on the two bars only for coaches, &c. at the bearings m m; the bottom is sometimes, turned up in a scroll form, for ornament only, in imitation of the upper part; the brace is hung by a shackle, or placed round the spring, and passing through a loop n, is fixed in a jack P, at the bottom, which is a little roller, to take up the length of the brace at pleasure, by which the body hangs.

Figure 8, is a spring used to light whiskeys or chairs, it is fixed on the axletree, by a jew's harp staple at o, which staple is united with the spring hoop and bolts through the axletree; it supports the weight at each end, by one or two loops p p, which are fixed at the bottom of the shafts; it is mostly fixed at one end, but has room to play at the other. These springs most generally have only one loop at the hind end, in which it is fixed, and the other end bears on a thin plate, fixed to the bottom of the shafts, sometimes two such springs are combined together for a gig, in a manner as shewn in *Figure* 4.

The axletrees of the carriage on which the wheel revolves, are of two sorts, the one is made flat, and called a bedded axletree, it being sunk in the timbers; the other is of an octagon form, flat only at the ends, which are bedded. The arms that pass through the wheels should be made perfectly round, and stronger at the shoulder than at the end, which is screwed to receive a nut; through this and the axletree the linch-pin passes to keep all tight. The nuts are made with a collar at the face, and a temporary collar or washer is driven on to the back of the arms, which forms two shoulders for the wheel to wear against, and helps to preserve the grease from running out. The axletrees being the principal, or only support of the carriage, the greatest attention and care should be given in the selection of good iron, and in the manufacture of the material; taking care that it is well wrought, and of sufficient strength, making it rather stronger than necessary, to avoid risking the life of the passenger, by the oversetting of the carriage, which mostly happens when an axletree breaks. By the bend of the axletrees the wheels are regulated to any width at bottom, to suit the tracks of the roads in which they are to run, and are confined in the carriage by means of clips, hoops and bolts.

The shape of the axletree between the shoulders, varies according to its situation, or the form of the timber with which it is united; those axle trees are the most firm that are flat bedded in the timber.

The axletree-boxes frequently called wheel boxes, are long casings fitted close to the arms of the axletree, and securely fixed in the wheel stocks or naves, they are usually made of wrought sheet iron, of a substance proportioned to the weight of the carriage. Their use is to contain a supply of grease, and to prevent the effects of friction, whereby the wheels

 are

are much assisted in their motion. There are many sorts of axletrees and boxes, either for the purpose of containing a longer supply of grease or oil; or to be more durable, or to secure the wheels, and lessen the draught. These are all great advantages, and though the expence is great, their utility must be more than adequate to it. The common axle-tree and box, are of a conical figure, being strongest at the back or shoulder, and regularly tapering to the end, through which the linch pin is fitted, a nut is screwed on the end of the axle, to keep the wheel on, the linch pin passes through this nut to prevent it from turning round, and coming off. This axle and box is most generally used, being simple and cheap, in comparison with the others; the box is the only part which wears, and is frequently obliged to be refitted to the arms, otherwise they give the wheel an unsteady motion, and soon exhaust the supply of grease.

Mr. Collinge of Westminster-road, has for many years past manufactured a patent cylindrial axle-tree and box, which has very great advantages over the common sort. They have been a considerable time in use, and their advantages have also been fully proved, which principally lie, 1st. in the length of time they wear,—2d. in the silent and steady motion they preserve to the wheels,—3d. the retaining the oil to prosecute a journey of two thousand miles without being once replenished; and 4th. they are very durable, and but little subject to be out of order.

Those axletrees and boxes have also gone through some sonsiderable improvements since their origin, and have met with such encouragement that it has induced other persons to copy them so closely, as scarcely to admit of a decision in favour of either.

Figure 5, is a section of the axletree and box, in which I, is the axle tree arm made as perfectly cylindrical as possible, and of a peculiarly hard surface, the middle reduced to contain the oil necessary to feed the axletrees at the two bearings b b, having a shoulder c, against which the wheel box K K, takes its bearings, the adjoining collar is grooved for a washer to preserve the oil, and prevent noise in its use, with a rim e e, on the collar of the axle-tree, to answer the use of the cuttoo. The end f, is double screwed to receive two nuts for securing the wheel; the one screw turns the way of the wheel, the other the reverse, and is meant as an additional security.

K K, is the wheel box cut through the middle, which is made of a very hard metal, nicely polished, and fitted to the arms, having a recess at the back part for containing a supply of oil. It has two shoulders c, the back one fits close to the rim of the collar, which it covers, the fore one projects without the surface of the wheel stock, and is screwed on the inside to receive the screw of the cap L, which covers the nut and receives the waste of oil, is mostly made of brass and screwed on, or in the box against the front of the wheel stock. This form of the cap is used to all but the common axletree.

The wheels to four wheel carriages, should be formed as nearly of a height as the appearance and construction will permit, and if not required for heavy work, or bad roads, the lighter they are the better. The fixtures from whence the draught is taken, should be placed rather above the centre of the largest wheel, for advantage of draught.

The members of a wheel are of three descriptions, viz.—the nave, the spokes, and the fellies: the nave is the stock, made of elm, in which all the spokes are fixed, and in which the axletree or wheel-box is confined to receive the axle arms. The spokes are straight, made of oak, firmly tenoned in the nave; these are the support of the fellies or wheel rim.

The fellies made of ash or beech, form the rim of the wheel, and are divided into short lengths, in the proportion of one to every two spokes; those are fixed on the spokes, and on them iron strakes are nailed.

The height of the wheels regulates the number of spokes and fellies that they are to contain, the larger the circumference of the wheel is, the greater number of spokes is required: they should not be more to any wheel than fifteen inches distance on the fellies.

The usual height of wheels extends to five feet 8 inches, and are divided in four proportions, to contain from 8 to 14 spokes, and half that number of fellies; these are denominated eights, tens, twelves, or fourteens, which are the numbers of spokes in a wheel, or fellies in a pair. The height which regulates the number for an eight-spoked wheel, should not exceed three feet 2 inches, for a ten, 4 feet 6 inches, for a twelve, 5 feet 4 inches, for a fourteen, 5 feet 8 inches; these are the greatest heights for the different numbers of spokes to each wheel. As the fore wheels of a four wheel carriage receives more stress than the hind ones, the rule is when the hind wheels are of that height to require 14 spokes; the fore ones, if under the necessary height before stated, should have twelve, never allowing the fore wheels to have more than two spokes less than what is needful for the hind ones.

The patent or bent timber wheel, has the rim of one piece, bent to the circle, instead of being put together in short lengths, or fellies, which are hewn to the shape; the strength of the bent timber is preserved while the other is destroyed; besides, it is hooped with one piece of iron, instead of being shod with strakes, and will often last twice the time in wear that the others will and has a much lighter and neater appearance, on which account it is often prefered.

The mock patent, or hooped wheel, comes very near the others in appearance and use, particularly if made

made with ash fellies; as the preservation of both lies chiefly in the hoops that the wheels are rimmed with. It is composed partly, on the patent plan, and partly on common method, having the timber the same as the strake, and the iron as the patent wheel.

The common sort of wheels are preferred by many, on account of their being more easily repaired, than the hooped or patent wheel, but, though the repairing of them is more difficult, yet they are much less subject to need it.

Boots and budgets are mostly understood as one article, though so differently called; they are intended for one purpose, which is that of carrying luggage, and are usually fixed on the fore part of the carriage, between the springs; the principal difference lies in this; one is made with a loose cover, and is properly the budget, being made convenient for trunks; these sort of budgets, for travelling carriages, or common post-chaises, are, by far, the most useful, the others are boots, of a trunk form, made more square, and adapted to town carriages, but can be of no other advantage than that of carrying loose hay, horse-cloths, &c. From one or other of these boots, conveniencies are sometimes made for the substitute of a coach-box, to save labour to the horse when the carriage is used for post-work, or to preserve an uninterrupted view from within.

Boots are frequently used at the fore end of phætons, and then mostly have the fore springs fixed thereto, by means of carved blocks, which are bolted to their sides; these usually have the step for the entrance to the body, fixed or hung. Boots and budgets are sometimes used to the hind part of travelling carriages, but more frequently to the hind parts of phætons, gigs, or curricles, and are of two sizes less than what are used to coaches or chariots.

Platforms, raisers, or blocks, are added to a carriage, either as matter of necessity or appearance, their use is to elevate and support the budget, boot, hind foot-board, and springs; they are generally placed on the side of the carriage, and relieve the inside framings from being obscured by the platforms, as they are lightened and moulded, and give the carriage a more airy appearance.

A handsome coach-box, is a great ornament to a carriage. Of these there are various sorts now introduced, to save unnecessary burden to the horse, and fatigue to the driver, which are two very material objects. The objection by many persons to a coach-box, is the obstruction it gives to the view; but they may be so adapted as not materially to affect the sight; and any convenience, however simple, is better than fatiguing both man and horse; but, to carriages used in town, a substantial coach-box is indispensably necessary, as it affords so material an advantage to the driver.

The standard coach-box is the most general and simple in use, as it is light, and convenient to remove; it is prefered for those carriages that are alternately used for town and country; these kind of boxes are simply fixed by means of plates, which clip the transom, and are stayed on the hind or boot bar, and fixed with collar-bolts.

The Salisbury boot, though bulky and of a heavy appearance, is by far the most convenient and fashionable coach-box in use; it is boot and coach-box together: and although it be apparently heavy, it is not more so than the common box and boot, together, as the inside is all a cavity, which is peculiarly convenient for luggage, having a large, flat bottom, which resting on the framings or blocks, makes it more steady than coach-boxes, on the common principles. This sort, however, is not so convenient to remove, and when taken off, the vacant space must be filled by another kind of budget, such as is usually put on to post-chaises.

We shall now proceed to some practical directions, with regard to the structure of a carriage.

Previously to making the body of a carriage, a drawing is made on a square canvas, by this the workman makes his patterns, marks out his timber, and saws it according to those patterns. The bottom which is the essential or main timber of the whole, (as all the rest principally depend upon it), is of a circular form, four feet long, compassed six inches from the centre, two inches deep, five inches and half wide in the centre, reduced at the ends to two inches. From the front of the bottom side, at the distance of two feet nine inches, close to the outer circle are framed the standing pillars, the length two feet six inches, one inch and three quarters thick, and two inches and three quarters deep, sweeping outward at the bottom, three inches to make the side of the body of a circular form, The front pillars are two feet six inches long, and nine inches wide at the bottom, reduced by an easy sweep to two inches and three quarters at the top, and the whole is two inches and three quarters thick, framed into the front of the bottom side two inches from the point on the outer circle. The corner pillar (two feet six inches long, two inches square, compassed at the bottom five inches, to make a continuation of the sweep of the bottom side, and form a circular quarter), is let into the extreme hind point of the bottom side on the outer circle. To the inside of the bottom side, is framed the front bar three feet long, two inches and an half square, at the distance of two inches from the point, the hind bar three feet four inches long, two inches and an half square, framed in the same manner three inches from the point. On the bottom of the bottom side, is fitted a wooden rocker, which continues from end to end, three inches wide, and four deep, in the centre, reduced to a point at the ends, fixed on with iron bolts, level with the inside of the bottom side. To the rocker the bottom, (consisting of deal boards grooved in each other), is nailed and strengthened

strengthened with iron plates, extending from back to front; the outside elbow is then framed, the length two feet one inch and a quarter thick, and three inches wide, in the middle reduced to one inch and an half at the ends, and turns up at the back part two inches, in an easy sweep is fixed on the standing pillar nineteen inches from the bottom side, and the turn up part on the corner pillar fourteen inches from the bottom side. In the hind pillar is framed the rail, three feet five inches long, one inch thick, four inches deep, 12 inches from the bottom side, over which at the distance of five inches, is framed the sword case rail of the same length, $1\frac{1}{2}$ inches square, compassed 1 inch, between the standing pillars is framed the seat rail, 4 feet long, 2 inches square, at the distance of 6 inches from the bottom side, square with that to the inside of the corner pillars, is screwed the back seat rail. The front latten rail, 3 feet seven inches long, $\frac{1}{4}$ inch thick, and $1\frac{1}{4}$ inches deep, is framed in the front pillars, distant from the bottom point one foot four inches. The fence rail of the same dimensions 10 inches higher. The doors are made with two upright pillars, both of the same dimensions and sweep as the standing pillars, one of which is called the hinge pillar, the other the shutting pillar, in which is framed a batten and fence rail, of the same dimensions and distance as the front 2 feet long, each compassed 1 inch on the outside, making a regular sweep with the elbow. In the bottom is framed the door bottom, 2 feet long, $2\frac{1}{4}$ inches thick, and $3\frac{1}{2}$ inches deep in the centre, compassed to the top of the bottom side.

The whole body being now framed, is grooved out to receive the pannels and rounded off for carving; when carved, the pannelling commences, which is of dry mahogany, planed thin to the grooves, the hind pannel is then cut to the size between the corner pillars; the lower back rail and bottom bar being then compassed by heat to the sweep of the pillar, and fixed to the bottom sides with the pillars, through which 2 iron bolts are driven and screwed on the inside.—The same process is observed with the front quarters, and doors, previous to which, battens are fixed to force the pannels on the sides to a circular form; the pannels are then strengthened on the inside by small pieces of wood $1\frac{1}{2}$ inches square and $\frac{1}{4}$ inch thick, fixed all over them with glue, which is called blocking.—The swordcase is then fixed in the hind part, by screwing two solid pieces of ash to the corner pillar projecting in the centre 8 inches, round which is turned by means of heat, a thin deal board strengthened inside with glue and canvas; the doors are then hung with brass hinges, fixed in the fore pillars, and fastened when shut with a spring lock and dovetail catch to the standing pillars, round the bottom and upright edges, are screwed brass rabbit plates, to give a good finish and hide the joints. The pillars are then prepared for the head. In the standing pillar is fixed a strong iron joint, to which is fitted the top pillar of two feet long, and three inches square, in the top of it is fixed the top door case with a joint and hinge, three inches from the standing pillar full length, three feet six inches by three inches in the centre, reduced at both ends to $2\frac{1}{4}$ inches; the front pillar of one foot ten inches in length, and $2\frac{1}{4}$ inches square, fastened with a double hinge joint, the front of the door case fitted at bottom, on the top of the front pillar, and fixed to that with a strong dovetail lock; the front top rail 3 feet 7 inches long, and $2\frac{1}{4}$ inches square, compassed 1 inch, and the top and bottom is fixed to the front part of the door cases. In the centre of the fore end is fixed the middle front pillar, length four feet, $2\frac{1}{4}$ inches wide, and $1\frac{1}{4}$ inches thick, in the centre of which pillar, is a hock joint, the upper part fastening with a dovetail plate and bolt. The whole of the pillars are then grooved out for the glasses and blinds: the doors and front outside, being now finished, the inside is boarded up with thin deal to receive the lining and preserve the glasses. The seat is then finished, by fixing boards on the seat rails, from the back pannel one foot eight inches. The hind upper quarter is formed by two compass slats (fixed to a neck plate in the standing pillar joint), 2 feet eight inches long, 2 inches at top, reduced to 1 inch at bottom and 1 inch thick; on the top of the hind slat, is fixed the back rail 3 feet 5 inches long, by 2 inches square, sweeped to correspond with the front rail, on the top of the other slat is fixed a hoopstick of the same, sweep 3 feet 10 inches, by 1 inch thick and 2 inches wide. On the top of the door case are fixed three more hoop sticks of the same dimensions, at the distance of 2 inches from each other. On the back of the elbow and to the corner pillar, is fixed a strong iron prop, which projects six inches from the body; secured inside by an iron stay, as also one on the top of the standing pillar projecting $1\frac{1}{4}$ inches, in the ends of which props the main joint is fixed; the lower slat and top rail is then fixed up 18 inches from the back rail; and the upper slat and hoopstick fixed 10 inches from it, on the elbows made to the sweep are fixed two strong iron plates 5 inches deep. The steps are then fixed in the centre of the door way in the bottom sides with bolts, width 11 inches depth, if treble, 11 inches, if single, 16 inches, cased round with deal to conceal them, (when the body is tummed); the body loops are fixed on the bottom of the rockers, with bolts and nut headed screws, the hind body loops 13 inches compressed to fancy: the front body loop to the head 18 inches from which proceeds a horn 6 inches long, jointed at top, to a split stay, which takes the foot board at 18 inches distance: the other part extending upwards to the bottom of the barouch seat 18 inches; there is also an iron stay fixed in a socket at the top part in front of the fore pillar, which fastens to the bottom of the seat at the distance

distance of 16 inches from the body; the width of the seat 15 inches, and length 31 inches, rounded at the hind corners, made of a solid board, on the top of which an iron is fixed 12 inches high, level with the outside; the foot board 31 inches long, 17 inches deep, and from the seat to the centre 18 inches, which finishes the body from the coach maker's bench.

The body being compleated from the coach maker's, it is usual next to cover the sword case with a piece of fine neats leather prepared for that purpose, and put on wet with paste or white lead to keep it from rising in the hollow part. A very great improvement has lately taken place in covering the top parts of coaches, and chariots, by putting the leather on whole, so as to prevent the possibility of wet penetrating, as was frequently the case when put on in separate pieces, and joined on each other by nails &c. The pannels of the body are painted three or four times with oil colour, and several times after with a composition of ground white lead, spruce or brown ochre, turpentine and varnish, and when hard, rubbed to a smooth surface with pumice stones and water, the colour whatever it may be, is laid a sufficient number of times to be solid, and varnished twice, previous to arms, if any being put on, afterwards varnished as often as required being various according to colour &c. &c. The process of painting the carriage, is by giving it a sufficient number of coats to fill up the grain of the wood, rubbing it between each coat with fine sand paper, till it becomes smooth, then ornament it by picking out, and varnish it as often as the nature of the colour requires, which never exceeds four times. The inside of the body is then trimmed, the art of which consists, in fitting a lining in it composed of cloth, leather lace &c. in the most ornamental and comfortable manner. The roof, the doors, front, bottom quarters, seatfall, and the bottom part of the cushions are usually cloth, the upper quarters, top and bottom back, elbows, and top of the cushions morocco. The process is this; first cut out the roof and all the larger parts of the lining; fit the pockets and falls on the front and doors, the pockets and falls are usually bound with broad lace. The morocco part of the lining with the exception of the cushions and elbows, are made with canvas backs, and bound with narrow lace, stuffed full with curled hair, and tufted with silk or worsted. When the lining is cut out and made up, proceed to line the inside of the sword case with serge, or shalloon of the colour of the lining, paste up slips of cloth round the lights, and paste cloth on the recess of the door left to contain the step: nail lace all round the lights, and finish round the same with narrow lace, called parting, fix in the elbows, the bottom, back, bottom quarters, top back, and top quarters, fixing up the roof which is fastened to the hoop sticks by narrow slips of list nailed to them, and screwed to the roof. The pillars are lined with slips of cloth, bound on each side with lace, through which the hand holders pass, and are nailed firm to the standing pillars, fix in the front, finishing the sides with the line of lace, which forms part of the front light, fix on the door lining, finishing the edges with a row of parting lace all round. The steps are mostly now very handsomely finished, one side being morocco, and lined with cloth or velvet, welted all round, and the front bound with broad lace. The treads are usually carpet, and besides a carpet fitted in the bottom; most carriages have spring curtains made of silk, on barrels with silvered ends, the cutting out and fixing up of which, forms a part of the inside trimming. The outside upper part is covered with oiled linen, previous to being covered with very strong grained neats leather, which is closed and welted together to fit the roof quarters and back, and when fixed on, completes the trimmings of the body, the seat, the top iron, is usually platted with neats leather, and japaned, round it a squab or cushion is fitted, the back part of strong leather, the front or inside cloth puckered in full, and welted all round, stuffed and tufted, and fixed in the top iron with straps made up with buckles. Inside the iron the cushion for the seat is fitted, and a fall is fixed along the front part, a deep valance all round the seat of very strong leather, and a leather from the foot board to the front of the seat, which is called a heel leather, bodies are a greater or less degree, ornamented with beading, of which there are three sorts, plated, brass, and queens metal; by the quality of which, buckles, handles, crests, and other ornaments are guided, on the front upper pillars are fixed the lamps, which have been much improved of late years, and are usually made to burn candles; the body and carriage thus prepared, are fixed together, by suspending the body loops to the springs of the carriages, by leather braces made of several strips, strongly sewed together with buckles fixed in them; there are also cheek and collar braces, fixed to the upper and lower part of the body, to prevent any violent motion which it would otherwise have.

Mr. Birch, of Great Queen-street, London, obtained, in the year 1807, a patent for an improvement in the construction of the roofs and upper quarters of Landaus, Barouches, and other carriages, the upper parts of which are made to fall down, which improvement is thus described.

Frame and fix in the top quarter rails to the tops of the standing pillars and slats, and fix the slats to the neck plates; rabbit the under parts of the standing pillars, the top quarter rails and the slats, and board them with thin deals, or any other proper material. Let the crown-pieces or cornice rails be long enough to bevel or mitre into the corners of the top of the standing pillars; and let in the hinges and thimble catches on the top of the crown-pieces and top of the quarter rails. Fix on the hoop sticks and back and front rails, and board them all up, except the

the two hoop sticks which are nearest to the hinges, which may be placed as close as possible, to admit of the head sticking conveniently low. Conceal or let in one or more boxed locks to the centre hoop sticks, or at least the hoop sticks which unite the thimble catches, and fix them so as that they may be opened by a key on the inside of the carriage. Stretch strong canvas, or other fit material, and nail it, or otherwise fasten it, both on the inside and the outside of the slats and elbows, and stuff it between with flocks or tow, or other fit material. Likewise stretch and nail on or fasten canvas, or any other proper material, to the top hoop-sticks, on the roof which are nearest the hinges before you put on the leather covering.

The patentee says, that in travelling, a carriage built upon this construction, will carry one or more imperials on its roof, without interfering with the regular process of opening it, and when in that situation, will remain without doing the least injury to its upper parts. Another advantage is mentioned, viz. that the spring curtains to the landaus remain without being removed, whereas those on the old plan were obliged to be taken down before there was a possibility of opening it.

END OF COACH-MAKING.

COMB-MAKING

COMB-MAKING.

The Comb is a well known instrument, made of horn, ivory, tortoise-shell, box, or holly-wood; and is used for separating, adjusting, cleansing, and ornamenting the hair. The commoner sorts of combs, are generally made of the horns of bullocks, or of elephants and sea horses teeth; some are made of tortoise-shell, and others of box, holly, and other hard woods.

Bullocks horns are thus prepared to be manufactured into combs; the tips are to be sawn off, after which they are to be held in the flame of a wood fire, till they become nearly as soft as leather. In this state they are split open on one side and pressed in a machine between two iron plates, then plunged into a trough of water, from which they come out hard and flat. When the horn is cut to the size intended for the required combs, several pieces are laid upon a pair of tongs, adapted to the business, over a fire, made chiefly of joiners shavings, to soften them. They are frequently turned, and when sufficiently soft, are put into a vice and screwed tight to complete the flattening. When this process is finished, the horns are perfectly flat and hard; they are then given to a man who shaves, planes, or scrapes off the rough parts with a knife, similar in shape to one used by coopers, having two handles, which the comb-maker works from him, across the grain of the horn, from one end of the intended comb to the other. When both sides are perfectly smooth, it is delivered to the person who cuts the teeth. This workman fastens it with wedges, by that part meant for the back, into an instrument called a *clam*. The clam has a long handle, which the workman places under him as he sits, by which means he renders the object of his work firm and steady, and he has, at the same time, both hands at liberty to be employed in the operation. The cutting of the teeth is commenced by a double saw, of which each blade is something like the small one with which joiners and cabinet-makers cut their fine work, with this he forms the teeth. As this instrument leaves the work square, and rather in a rough state, particularly in the inside edge of each tooth, it is followed by another about the size and shape of a case knife, having teeth like a file, on each flat side. After this, two others of the same shape, but each finer cut, than the other follow. One stroke on each side of the comb is then given by a rasping tool, which is used to take of any roughness that may remain on the sides of the teeth; it is now delivered to another operator, who polishes it with rotten stone and oil, applying them with a piece of buff leather.

The process used for making ivory-combs, is nearly the same as that just described, excepting that the ivory is first sawn into thin slices. The ivory from Ceylon, is reckoned the best, as being less liable to turn yellow, by exposure to the atmosphere. The whiteness which ivory acquires, depends chiefly on the degree of dryness which it has acquired. When yellow, its gelatinous matter is altered by the air, and appears combined with the oxygon of the atmosphere. Heat cannot be made use of for making ivory pliant, though it is rendered softer by being exposed to that agent. It is, as we have observed, divided by the saw, and for very delicate work, the operation is sometimes performed underwater, to prevent its being heated or rent by the action of the tool. It is polished with pumice stone and tripoli. Ivory has been said to become soft by being placed in mustard, but both ivory and bone are softened by being immersed in an alkaline-ley made of soda and quick-lime.

We shall now give some account of the method of cutting combs adopted by Mr. William Bunday, of Camden town, and who obtained his Majety's letters patent for the invention. The term of his exclusive privilege being we apprehend compleated, it is open to any manufacturer to make what use he pleases of the discovery.

It appears, says the writer in the monthly magazine, at first sight to be a singular circumstance, that in a country famous for its attention to mechanical processes, the teeth of ivory combs, should be cut one stroke after the other, by the human hand, assisted by no other tool than a pair of saws rudely fastened in a wooden back, and kept asunder, by means of a small slip of wood. With these rough implements, however it is, that the very delicate superfine ivory combs, containing from 50 to 60 teeth in an inch, are manufactured. It may readily be conceived, that the imaginations of mechanical men, must have been employed in an attempt to solve the practical problem of constructing a machine, which without skill in the agent or first mover, might perform all that men converted by practice, into a kind of living machines, are capable of doing, but with less cost, or greater product, in proportion, as it is

easier

easier to maintain the one than the other. Accordingly it is not difficult to find traces of attempts of this kind during the last 40 years, in the traditions of our manufacturing towns and counties. From what causes their failure may have arisen, since none of them have been established to supersede the old practice, is not easy to discover, but it is certain, that Mr. Bundy's machine, is the first and only one which has yet appeared at the patent office. Its construction is as follows:

An iron fly wheel of three feet in diameter, is moved by a crank and treadle, or by any other power or means of application. On the same axis, is a wheel or pulley of 15 inches diameter, which by a gut, drives another pulley of nine inches attached to a puppet head above, sheers resembling those of a common foot lathe. An arbor is driven by this upper wheel, in the same manner as work is thrown round between centres before the mandrell in the common lathe. On the arbor are fixed a number of circular cutters, about two inches diameter, corresponding to the notches intended to be cut in the combs. These cutters are all of a thickness, and have brass washers between them, and also from another arbor in a frame there are steel pieces, called guiders, which stand between the cutters, and keep them regularly asunder, just above the place where the comb enters.

The comb is held by a plate and two screws, upon the top of a block or carriage, which runs off and on by means of a platform, and dovetail upon the lathe bed. The comb moves in its own plane, right onward, to the centre or axis of the cutters, and the carriage is driven by a screw of ten threads in the inch, into which a knife edge from the carriage falls, instead of a nut. On the extremity or tail of the screw is fixed a spur wheel of thirty teeth driven by an endless screw, the arbor of which last is of course parallel to the arbor of the cutters. It is driven by a pulley of six inches concetric with the cutting arbor, and itself has a pulley of three.

Hence if the great wheel be moved once round, per second, the arbor will revolve $\frac{15}{9}$ times and the endless screw arbor $\frac{30}{9}$ times but from the dimensions of the screw, 30 revolutions of the endless screw make $\frac{1}{10}$ inch of the tooth, or 150 revolutions make $\frac{1}{2}$ inch. With this length of tooth, the great wheel will revolve 45 times, and the cutting arbor 75 times. One side of the comb will therefore be cut in three quarters of a minute.

The combs are pointed by applying them to an arbor, clothed with cutters, with chamfered edges and teeth $\frac{1}{20}$ inch deep, they are applied by the hand. This arbor is driven by a wheel on the crank axis.

The cutters are made of tempered steel, as are also the guides, the teeth of the cutters are set so as to clear the back or following part from the friction in the cut.

The cutters, the cutter washers, the guides, and the guide washers, are all ground flat and thin, upon a brass plate, in the same manner as optical work is ground; during which operation, the piece is retained again on an upper movable plate, of its own size, by means of a circular rim or edge which is adjustable by screws, so as to form a deeper or shallower cell, as may be required,

The guides are one twentieth part thinner than the washers of the cutters, and the guide washers are somewhat thicker than the cutters, and there are grooves in the sides of the guides that the teeth of the cutters may pass clear, notwithstanding their side sets.

The writer had an opportunity of examining one of the cutters of this artist, which had been given by him to a friend. It was beautifully wrought, very uniform in its thickness, which was about the $\frac{1}{160}$ of an inch, and the sets of the teeth which seemed to have been affected by the blow of a punch on every other tooth was extremely accurate, it was not perfectly flat, but had that kind of flexure which workman call a buckle. He also saw an ivory comb of 40 teeth in the inch, which was very uniform, and equal to the best work done by hand, except that the cut seemed too wide.

It appears to be placed beyond a doubt, that combs may really be cut in this way; but whether to advantage, must depend on the cast and durability of the cutters, which it is to be feared, may be bended and spoiled in a course of work, by their incessant friction between the guides. It may also be remarked, that they cannot be taken off the arbor to sharpen or repair, and be put on again without changing the degree of fineness in the comb they will cut. For if we suppose an error of one thousanth of an inch in grinding or callipering the cutters and washers, or in the different force of screwing them together on the arbor; this will make a difference of one third of an inch, or the breadth of seventeen teeth in a superfine comb. No. 6, which if coarser would bring it more than half way to the sort called dandriff, or if finer, would equal the box-comb. Besides, which a much less difference would totally destroy the agreement or fitting between cutting and pointing. A more particular account of the patent invention, with engravings, may be found in the repertory of arts for the year 1796.

Tortoise shell combs, as they are called, are very much used. It has, however, been properly observed by authors, that the hard strong covering which encloses tortoises, and which is used on these occasions, is improperly denominated a shell; being of a bony contexture, but covered on the outside with scales, or rather plates of a horny substance. There are two general kinds of tortoises, viz. the land and the sea tortoise; the latter is divided into many distinct species, but if the *testudo-imbricata* of Linnæus, which alone furnishes that beautiful shell so much

much admired in European countries. The spoils of the tortoise consist in thirteen leaves or scales, eight of them are flat, and five bent. The best tortoise shell is thick, clear, transparent, of the colour of antimony, sprinkled with brown and white.

Tortoise shell, like horn, becomes soft in a moderate heat, as that of boiling water, so as to be pressed in a mould, into any form, the shell being previously cut into plates of a proper size. Two plates may likewise be united into one by heat and pressure, the edges being thoroughly cleaned, and made to fit close to one another. The tortoise shell is conveniently heated for this purpose by applying a hot iron above and beneath the juncture, with the interposition of a wet cloth, to prevent the shell from being scorched by the irons; these irons should be pretty thick that they may not loose their heat before the union is effected.

Tortoise shell being in so much request, many methods have been invented for the purpose of *staining* horn so as to imitate tortoise shell; of which the following is one.

The horn to be dyed, being first pressed into a flat form, is to be spread over with a kind of paste made of two parts of quick lime and one of litharge, brought into a proper degree of consistency with soap-ley. This paste must be put over all the parts of the horn except such as are intended to be left transparent, to give it a nearer resemblance to tortoise shell; the horn must remain in this state till the paste be quite dry, when it is to be rubbed off. It requires a considerable share of taste, and judgement to dispose the paste in such a manner as to form a variety of transparent parts, of different magnitudes and figures, to look like nature. Some parts are, by a neat process rendered semi-transparent, which is effected by mixing whitening with a part of the paste, to weaken its operation in particular places; by this means spots of a reddish brown will be produced, so as greatly to increase the beauty of the work. Horn thus dyed is manufactured into combs, which are frequently sold for real tortoise shell, we shall now add two or three other directions on subjects connected with this business.

To make horn soft.—Take wood-ashes and quick lime; of these make a strong ley, and filter it clear, boil the shavings or chips of horn therein, and they will soon be reduced to a paste, this may be coloured, and cast into any form required.

To prepare horn leaves in imitation of tortoise-shell.—Take of quick lime one pound, and litharge of silver eight ounces, mix them into a paste with urine, and make spots with it, in what form or shape you please, on both sides of the horn; when dry, rub off the powder, and repeat this as many times as necessary. Then take vermillion, prepared with size, lay it all over one side of the horn, as also on the wood, to which you intend to fasten it. For raised work, form the horn in a mould of any shape, and when dry give it colour with the aforesaid paste and vermillion, then lay clear glue, both on the horn and the wood on which it is to be fixed, and close it together. This work is to be done in rather a warm place, it is then to stand all night; the roughnesses are to be cut or filed off, and the horn polished with tripoli and linseed oil. Work finished in this manner is well adapted for ladies combs.

Another method of imitating tortoise-shell with horns.—Take of Nitrous acid two ounces, and of fine silver one drachm; let the silver be dissolved, and having spotted or marbled your horn with wax, strike the solution over it, let it dry of itself, and the horn will be in those places which are free from wax, of a brown or black colour.

To dye Ivory green, to be used as combs.—A green dye may be given to ivory, by steeping it in nitrous acid, tinged with copper or verdigris, or in two parts of verdigris, and one of sal ammoniac, ground well together, with strong white wine vinegar poured on them; and by converting the nitrous acid into aqua regia, by dissolving a fourth part of its weight of sal ammoniac in it, ivory may be stained of a fine purple colour.

To dye Ivory, &c. with other colours.—Ivory, bone, horn, and other substances adapted to the manufacture of combs may be stained yellow, by boiling them first in a solution of one pound of allum in two quarts of water, and then boiling them in a solution of turmeric root. Ivory, &c. may be stained blue, by first staining it green, and then dipping it in a solution of pearl ashes, made strong, and boiling hot. It may be accomplished also by boiling in the tincture of indigo, prepared by the dyers, and afterwards in a solution of tartar, made by dissolving three ounces of white tartar, or cream of tartar in a quart of water.

Combs are sometimes set with brilliant stones, pearls, and even diamonds; some are studded with cut steel, these are of different shapes, and are used to fasten up the hair when ladies dress without caps. Of course combs may be had of all prices from a few pence to almost any sum. Journeymen comb makers will earn from 25s. to two guineas per week.

END OF COMB-MAKING.

COOPERING.

COOPERING consists in manufacturing casks and vessels used for containing and transporting all kinds of liquids, &c. It must have been a trade almost coeval with our existence, it being of the very first necessity. The art of coopering has enabled man to possess and retain the richest viands of foreign climes. It promotes and facilitates the export and import of the produce of distant countries, which have enriched the merchant, supplied the wants and luxuries of the people, enriched the revenues, and given spirit to navigation. It is impossible in reflecting on the utility of this trade, not to feel that it occupies a much greater space in our existence than it at first appears to do.

It supplies in the first place, all the necessary facilitates of our very extensive breweries and distilleries. It enables our colonies to exist, by offering a ready transit to their produce, and in fine, it is a trade which has developed to unreflecting man, the bounties of divine providence in a most especial manner. The trade in London is divided into several ramifications, and the persons carrying it on as well as the journeymen, confine themselves respectively. They are designated by first "Butt Cooper," whose employ consists in manufacturing all kinds of casks for breweries, &c. also the Puncheons and Hogsheads for distilleries. Their working tools are but few in number, the first, an "adze," similar to the same tool made use of by Carpenters, except the handle only being about ten inches long, he has also an axe, with this and the adze he reduces the staves to the form he wishes, he has also a bench, consisting of a piece of simple plank, and generally 4 or 5 feet long, and one foot wide, standing on four feet, raised to about 2 feet high at one end, and 18 inches at the other, forming an inclined plane on its top; there is a stop and two upright keeps at each end of the top of the bench, which serve the purpose of keeping the stave firmly on it, in the operation of jointing. Their planes consist of two or three only, called "jointers," similar to the same kind of tool used by Joiners. It is used by the butt cooper from 3 to 4 feet long, and with which he makes all his joints, it requires to be kept in good order, and to be exactly true on its face, and the mouth of the plane small, with the iron thin and sharp.

The shave is a machine similar to a tool called a "spoke-shave," of rather larger dimensions than the common ones used by Carpenters; but coopers use them of various sizes, it is a sharpened piece of hardened metal, with two legs let into a small block of beech-wood, rounded on the face, and shaped at the ends so as to be held in the hand by the workmen, the iron is sharpened as planes are, and it is fixed in the stock by two small wedges. With this tool the cooper smooths and finishes the inside and outside of all his casks, rounds and shapes their edges, and in fine finishes his work for use. The tool called a tooth, commonly "the old woman's tooth," is made not unlike the "shave," except the iron which is in fact the tooth, it is very narrow approaching an arris, and it is kept sharp, and used for making grooves round the top and bottom of the staves, to receive the ends of the cask. They use also a series of Bitts, called centre and doweling Bitts, the former are used for making perforations to insert cocks and other conveniences for filling or emptying the casks, the latter for boring the edges of two opposite joints, in the tops and bottoms of vessels required to be doweled together.

Doweling is no more than fixing in oaken pins in the joints; and made use of, only to large vessels to prevent the joints from swagging from their places; it is of the greatest utility, and a good cooper never neglects to do it; it is confined to the tops and bottoms only. A hoop "technically" is to the cooper a model, into which he fits all his staves; this model or hoop is of ascertained dimensions, and is as various as the numerous different vessels made use of, for instance, they have a hoop for butts, hogsheads, puncheons, barrels and all other casks required for the different quantities of liquids to be vended at a butt coopery, on a large scale. These hoops are laid down, and the work is divided among the most expert in their several ways. Some men are employed in hewing the staves and reducing them to their lengths, others in jointing and fitting them into the hoop, and some in preparing the tops and bottoms, while others are cleaning and smoothing the staves to receive the ends and final hooping. The staves made use of by the but cooper, are invariably of oak, and until very lately, wholly imported from the Baltic, and sold in the market by a merchant, called the stave merchant. The staves are imported in the several lengths required, and sold by the thousand, under the following designations, viz Pipe staves about five feet 6 inches long, two inches thick and six inches wide; hogshead staves four feet long; barrel staves three feet 6 inches long

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There are also to be met with, long and short headings, the former run about 30 inches in length, and the latter from 20 to 24 inches; these various staves are found to meet most of the required purposes of coopery. The retail merchant sorts and divides them for the consumer into the best pipe staves, seconds &c and the same to the hogshead, and barrell staves. The headings are sold generally as imported, the Dantzick and Hamboro staves are considered the best. Although great quantites are imported from Riga, Memel and Koningsberg; the pipe staves from Dantzick or Hamboro, will fetch from £200 to £250 per thousand, of six score to the hundred, and they rose lately when all communication with the Baltic was stopped, as high as £500 per thousand, and the smaller staves in a proportion. This event gave rise to the introduction of staves from Canada, which soon superseded the necessity of the importation from the Baltic, and there is now in the market from our own possessions, in America abundance of staves of all descriptions; sold by the designation of Quebec and Canada staves, and at two thirds the price of those from the Baltic, they are however, not found to be so durable, but they work better, and make a neater utensil. The Dantzick staves still continue to be purchased for the Breweries, in preference to the American, from the experience of its superiority in strength and durability. All the American wood, possesses more beauty than strength. In the article of fir, of which there is an immense consumption in these Kingdoms, and which have latterly received almost their whole supply from Canada, and in order to encourage the importation from these settlements, the import duties have been made considerably less, than from the Baltic, but in building as in coopery, the cleanness and straightness of the grain of the timber, is a poor set off for its want of strength and durability; which qualtities the timbers from America, certainly want in comparison of those from northern Europe. Iron the cooper is not in need off, because its place can be supplied with other materials; except for his working tools. But England abounding in iron, it is found economical to make our hooping of that metal. Iron hoops are obviously the best for the butt cooper, whose staves are usually of good substance; but in cases in which the staves are thin, iron hoops should be avoided, or at least but partially employed. The oxide of iron of which these hoops supply abundance (commonly known as rust) eats away and destroys the wood with which it comes in contact, as well as the hooping itself; Foreign casks are seldom bound by iron; not always from the want of the metal, but from fancying that it may have chalybeate qualities upon their contents; it is particularly avoided in France, and indeed, in all wine countries, and in France the best coopery is practised. The hooping is sold as most iron work usually is, by the hundred, in various lengths, previously wrought in a mill at the furnaces, of great variety of thickness, the hooping is cut by the cooper, to the length he requires to hoop his butts, or other vessel, punched at the lap, and cold rivetted. Previously to putting on the hooping, the staves are dryed either by being exposed to an open fire, or in kilns, the latter is now the most approved in large manufacturies.

Rundlet-cooper is a second branch of this trade, he makes use of all the tools, used by the butt cooper, except, perhaps his collection may be on a smaller scale. This manufacturer makes the bottles of various small contents for the use of the distiller, who sends out his spirits in them, consisting of, from 1 gallon bottles and upwards to 20 gallons; he uses the long and short headings, which he rends into two or more in thickness, according to the substance required in his bottles. This is an extensive branch of business, if it be considered how numerous our wants are made by the ingenuity of the distiller, whose chief concern is in giving a zest to the palate; and his success is too apparent in the multiplied nostrums offered, to the weary public, under the appellation of cordials. As these are increased, the rundlet cooper finds his account important.

Dry cooper finds his employment in manufacturing hogsheads, and casks for the containing of every kind of dry produce, the leading feature of the consumption in his line, is in making hogsheads for sugar. His tools are of the same description as before named, but he works the staves out of all kinds of wood, and is not obliged to be so neat in his fittings as the butt or rundlet cooper. It is an extensive line of business at all sea-ports, in which great exports are constantly making, he supplies casks to pack the supplies in, of all dry natures, for both army and navy, as the cloathing and hats; besides military stores, are, for convenience usually packed in casks. His business is also extensive in supplying convenient security in packages for the Apothecary general to the army, whose medicines are forwarded in a dry state securely enclosed in casks, prepared by the dry cooper.

White cooper, his employ comes home to every housekeeper, because in every establishment, is to be recognised some machine or other supplied to it by his industry. He manufactures all domestic utensils, such as are used in private brewing, in washing, dairies, in making churns, pails, and every convenience required in all the multiplied purposes of our domestic economy. At the white coopers, is to be found the most extensive employment of the staves called long and short headings; he is the greatest consumer of this article; he proceeds in a similar way in the manufactory of his goods, as is described under the head of butt cooper; but he rends his staves into several thicknesses, in order to make his utensils lighter and better adapted to their required purposes, he makes use of many different kinds of hoops, the iron hoops he procures by weight ready

ready milled and fit for use, which he adopts and cold rivets on all his goods bound by iron hooping; many of the articles manufactured by this tradesman, are secured by wooden hoops, for instance; all tubs used in laundries and dairies; these hoops known to the trade by "white hoops" are rended out of ash wood, and are of various substance for use. When this hoop is neatly cleaned up, it gives a cleanliness to the appearance of the vessels, and so finished is always prefered for the laundry and dairy. This kind of hoop is sold at the white hoop merchants, and the average price is from 40 to 50s. per hundred of 6 score. There are at the same depot, hoops of all descriptions, for the numerous inferior vessels, and of prices varying from 12s. per hundred to 30s. The white cooper finding his account with the housekeeper, usually keeps a shop, at which place commonly may be found exposed for sale, almost every article required in the domestic concerns of an establishment. In London to this branch of coopery, is sometimes added turnery, which in a retail shop, supplies all kinds of brushes and baskets, with many other little things, required for comfort and convenience, at the white coopers, all jobs are done in repairs, and alteration to casks and coopery of every description.

The manufacture of backs and vats for brewers and distillers, does not necessarily belong to coopery, it is a distinct branch of trade, and performed by persons called back and vat makers; they work in English oak commonly, and they take care to select that which is soundest and freest from knots, and saw it out into two inch, 2½ and 3 inch planks, which are laid by for seasoning. Carpenters work at this business, as the machines are of all shapes; for instance, the coolers for breweries, are commonly oblong squares, and are made by this tradesman. The only particulars required in making good coolers, is that the sides be adequately strong, the joints well fitted, and the whole not too deep, the sides of a cooler of ordinary dimensions, should be at least 2½ inches thick, the joints should be well plowed and tongued, the bottoms should be jointed in a similar way, and these will require dowelling; the ends are grooved into the sides, and the whole is spilled together with iron pins; these vessels are sometimes scorched or charred in their insides, for the double purpose of preventing their decay, and also the too rapid acidity of the liquor exposed to cool in them.

Mash-tuns, the under and jack backs, working tuns, and store vats, for the still and brewhouse, get best manufactured at the back makers, as every thing he does is on a large scale. He keeps materials better adapted to its well performance than can be found at the butt coopers. All the above vessels are usually made round, they are prepared in a similar manner to the work of the butt maker, except, generally from staves of English oak; some of these vats are immense, particularly those called store vats, containing from 20 to 30 butts and upwards; the hoops are necessarily of iron, very strong and frequently joined by a nut and screw rivet, which allows of removal in case of repair or accident.

Wine cooper is a person employed in drawing off, bottling and packing wine, spirits, or malt liquor; in London, many persons follow this business only, and keep in their employ several assistants, it is common for persons of the first consequence to employ the wine cooper to take charge of their wines. He has stipulated prices for all he does, charging his bottling off by the pipe, half pipe, or as it may happen; he keeps a working butt cooper in his employ to repair and job in the upholding, and supporting the several casks in which wine and spirits are contained.

Under the trade of the cooper, may be introduced the manufacture of canteens, these are small vessels made of wood, in which soldiers when on their march, or in the field, carry their liquor. These vessels were formerly made of tin, but the use of wooden canteens has for some time been general in the british armies. They are made, in shape, very like barrels, cylindrical, seven inches and a half in diameter, and four inches long on the outside, holding three pints. These vessels have for some years since been manufactured on a larger scale by Mr. George Smart of Ordnance Wharf, Westminster Bridge, who has contrived a very complete set of machines for abridging of labour in the business.

The wood made use of is the best foreign oak, which is first sawn out into boards a quarter of an inch thick; these, after they are planed, are cut in the direction of the grain, in slips of an inch and a quarter broad, by means of a circular saw called a ripping saw. This saw is made of steel plate with very fine teeth, and on the end of its axis is a pulley, turned by a band going round it, and likewise round a large drum driven by a horse-wheel; the plane of the saw in the ripping machine is not fixed exactly at right angles to the bench, but at a proper angle for the staves of the canteen, which are cut from these slips, when put together to form a cylinder of the true size. The accuracy with which these saws cut, is so great that the edges do not require to be planed. There is a guide for the edge of the board as it is cut, which, for cutting slips of different widths, can be moved nearer to, or farther from the saw, by loosening the thumb-nut, the screw from which moves in an opening, in the bench, and is always kept parallel to the plane of the saw by two levers.

A workman takes one of the boards, and puts its edge against the guide; when he pushes it forward, the saw cuts it along into slips very quick; these slips are delivered to another workman, who uses a cross-cutting saw. There is a groove cut in the bench to receive a slider, across one end of which another piece is fixed, having a notch in the underside

side for the saw to pass through when it is slid forwards. The end of the slip which is to be cross-cut, is pushed up close to the guide, and the piece and slide are driven towards the saw which cuts it off instantly; the slide is then drawn back, and the slip pushed up to the guide for another length as before. These pieces which are 4¼ inches long and 1¼ broad, are for the staves of the canteen. The staves which have a hole in them for the cork or bung, are first cut out by the same means as the common staves, but they are of twice the thickness. The hole is bored in the following manner; there is a spindle with a pulley on it, turned by a band, going quite round it, and a drum, with a velocity of 1800 revolutions in a minute; at the end of this is a male screw to fasten on a common borer or centre bit; there are two smooth wooden rails, for a slider to move upon, in the middle of which is fastened a small piece of wood having a hole through it, and a shoulder. The workman takes a stave out of the box, and putting one of its ends against the shoulder of the slider, and one of its edges against the bottom board, holds it fast, while he pushes it forward against the borer.

When the common and bung staves are thus prepared, they are given to another workman, who has a thick block of wood, in which is turned a circular groove about half an inch deep, and a quarter of an inch wide, which is for setting the staves up in; when the groove is filled with staves, the man takes a screw-hoop, which is a thin plate of steel, with a square lump at one end, and another near the other end, to receive a screw, to lighten it; the workman puts this tool over the staves, and turns the screw, till the staves are brought close enough, to drive on the iron truss hoop. These cylinders are taken to another person who turns them in a lathe, which is set to work, and the ends of the staves are turned smooth by a tool laid in a notch of the rest; another tool like a hook is then used, for cutting the groove on the inside of the staves for receiving the head. The boards for the heads are first sawn out, into squares, which are then cut circular by a lathe.

The next operation is heading and hooping the canteens, which is done by knocking off one of the truss hoops, and putting one of the heads into the groove; the staves are then tightened by the screw-hoop, so that the hoop of the canteen may be driven on; the other head is then put in, and the hoop on, in the same manner. After this the wires are fixed, which are for receiving the belt by which the canteen is carried by the soldier. They are next to be proved, by pouring a small quantity of hot water into them, and stopping the cork-hole with a wooden stopper, they are shaken briskly, and the hot water rarefying the air within, the same will rush out violently and discover any small leak that may be left.

The slips of iron plate for the hoops are cut from large plates of sheet-iron by sheats, worked with a powerful lever; the plate is pushed forwards from behind by one man, while another is lifting up the lever till it reaches the stops; the man at the handle then pushes it down, and cuts the length of a hoop at once off the plate, when the lever is down the underside of it pushes down the stop, so that the hoop may fall off, and the lever is lifted up to cut another hoop as before.

The holes for the rivets of the hoops are next punched by a machine formed by a lever, having a punch fixed in it; under this is fixed a dove-tailed groove to hold a piece of steel, which has several holes of different sizes in it, to suit different punches, any one of which can be brought under the punch, and fixed by screws, in each side of the groove; across the top of the groove an iron plate is fixed, with a hole in it, for the punch to go through; its use is to prevent the hoop, which is put under it, after it is punched, from rising with the punch. The boy who works this machine lifts up the lever, puts one end of the hoop under the plate, and then pushes it down, which makes the hole; he then lifts it up again, and puts the other end under to make the hole in it, first hooking the hole before made over a pin which determines its length.

After the hole is punched, a machine is used to cut the ends of the hoops round, they are then bent round a block, and rivetted in the common way. By these ingenious contrivances, the operations are rendered so simple, that a good workman will head and hoop 200 canteens in about 14 hours; and two active men will cut with the shears 60 hoops in a minute. Great attention, we are told, must be paid to keeping the truss hoops always of the proper size, as they are apt to expand with continual use, and if they are too large, the heads of the canteens will not fit.

We must not finish this article without noticing an invention of Mr. Smart, for which he, obtained in the month of May last, his Majesty's letters patent, which is for an improved method of preparing timber so as to prevent its shrinking. The great inconvenience in the article of coopering is that the vessels being kept a considerable time in dry places are apt to fall to pieces, and thereby require additional and heavy expence in repairs or refitting. This has been the case with canteens, so that government have, from time to time, been put to vast expences in remaking, or at least in rejoining vessels that, perhaps, they have never used. It is difficult to manufacture such small vessels as we are speaking of perfectly free from leakage, and upon the old plan, perhaps ten per cent, in the number made, were returned on the hands of the manufacturer, being found to leak, when examined in the way already described; but since the method has been adopted, of which we are now going to give an account, we are credibly informed that not a single canteen

teen out of 30,000 has been returned as unfit on account of leakage. The nature of the invention we shall give chiefly in the words of the patentee; in many cases, in which the shrinkage occasioned in timber, by exposure to hot or dry air, or to any circumstance which abstracts moisture from the pores of wood is productive of injurious consequences: this is prevented by a previous compression of the wood, with a proper application of certain mechanical powers, into a less volume, than can ever be induced by the common causes which occasion shrinkage. This invention will be particularly useful to coopers, vat-makers, and likewise to builders and other persons who work in wood, and to whom it is of importance, that their work should not fail by heat and dryness. Thus in preparing staves for vats or casks, the staves are cut square on the edges, and then passed between a pair of rollers made with bevelled grooves in them, so as to press the wood on the edges into the bevel that is necessary to give the required rotundity according to the width of the staves, that are to form the casks and vats. The heading boards are passed through parallel rollers, loaded in proportion as the wood is hard and thick. For canteens or the smaller kinds of work, I press, says Mr. Smart, my staves with a screw-press, or lever which not only bevels them, but its action on the inner edges gives them a degree of curvature which facilitates the subsequent cooperage. Vessels made of staves previously submitted to such a process as I have described by any means fitted to produce the effect required will be always tight, whether full or empty. The wood being pressed into a closer state than it could ever attain by shrinking, nor do the stave require the insertion of rushes between the joints, as is often done, in the common ways of forming casks, and other vessels destined to contain liquors.—Again, in carpentering; the best performed trussing commonly gives way, owing to the subsequent shrinkage of the timber; this evil is prevented by my invention; all that is necessary, being to press, by means of a screw-press, what is commonly called the crown of the king-post, and also the base of the truss into a less volume than drying could ever occasion, before inserting the trusses. The boards to be employed for flooring, should be passed edge ways between rollers to close the fibres of the wood, before laying down the floor. From the above description, no competent workman will be at a loss to adapt his wood to the purpose to which it is to be applied.

END OF COOPERING.

COTTON-MANUFACTURE

COTTON-MANUFACTURE.

This, which is now the most important of our national manufacture, is of modern date. The spinning of cotton into thread, which is the most laborious and important part of the whole manufacture, was before the year 1767, performed only by hand, one person spinning a single thread at a time, by a simple machine. Since this period, machinery has been introduced to perform every part of the spinning process, in the most perfect and expeditious manner that can be conceived, and it is these machines which have enabled the English manufacturers to supersede all others in this branch; and in the course of half a century, to raise the cotton trade from the humblest of the domestic arts, which was formerly confined to the fire side of the labouring poor, and produced few articles except for our home consumption, to one of the staple trades of the country, affording at the same time the greatest variety of fabrics for our internal consumption, suited as well for the ordinary wants and comforts, as for the elegancies of life, and giving us a decided superiority in every market in the world, except in the delicate fine muslins from India. The patient natives of the east still maintain their ancient pre-eminence in the finer kinds of muslin, some of which of most exquisite beauty and fineness are sold in this country, as high as ten or twelve guineas per yard. In productions like these, no rivalship can exist; In India, they are looked upon as master pieces of art, and the time employed by an Indian weaver in their production, would ruin an European manufacturer.

The common kinds of Indian muslins, or such as are adapted to general use, are also preferred by our English ladies, to those of our home manufacture, as enduring greater hardships, and as better retaining their white colour. This excellence which exists to a certain degree, is the result of no superiority in the manufacturing processes, but in the raw material, of which that of India is the finest and best in the world.

The manner of manufacturing cotton in India, forms a remarkable contrast to the European method. In Europe a vast apparatus of machinery is used in every part of the process, while in India, the simplest instruments are made to produce fabricks of that exquisite fineness, which it is the boast of our manufacturers to imitate, and which, as yet, they can scarcely equal. The cotton-wool in India, is prepared for the spinner without cards, is spun for the weaver without wheels, and is woven in looms, which the weaver can move from one place to another, with as much facility as the web itself The operation which our manufacturers perform by carding engines, is executed by the Indians with nothing more than a bow, the string of which by repeated vibrations, raises the cotton-wool to a downy fleece, in the same way that our hatters prepare their furs for felting, an operation which may be seen in most towns.—*(See Hat-making)*

The fine thread or yarn, from which the choicest Indian muslins are made, are spun from cotton, thus prepared by the distaff and spindle, which it is evident, was practised by the Romans, Greeks, and Egyptians, from their fables and their sculptures. Nothing can be more simple than this implement, but it requires much dexterity to work it; this yarn is then woven in the loom, which is the most simple that can be imagined, consisting merely of two bamboo rollers, one for the warp, and the other for the web, and a pair of geer. The shuttle performs the double office, of shuttle and batten, and for this purpose is made like a large netting needle, and of a length somewhat exceeding the breadth of the piece.

This apparatus the weaver carries to whatever tree affords a shade most grateful to him, under which he digs a hole, large enough to contain his legs, and the lower part of the geer; he then stretches his warp, by fastening his bamboo rollers at a due distance from each other, on the turf, by wooden pins; the balances of the geer he fastens to some convenient branch of the tree over his head, two loops underneath the geer in which he inserts, his great toes serve instead of treadles, and his long shuttle which also performs the office of batten, draws the weft, throws the warp, and afterwards strikes it up close to the web. In such looms as this are made those admirable muslins whose delicate texture the European could never equal, with all his complicated machinery. The processes of which we shall now explain.

The raw cotton-wool, is the produce of a plant about the size of a current bush, a native of the torrid zone, though it is produced in parts of Turkey, as far as 45° north latitude, the cotton is separated from the seeds of the plant by a mill, and after this

this preparation it is packed up in bags for the European market, where the great consumption lies. The finest sort comes from Bengal and the coast of Coromandel, where cotton makes a very considerable article in commerce.

But the greatest part of the cotton manufactured in this country, is the produce of the West India islands, and Smyrna, the most esteemed is white, long, and soft. Those who buy it in bales should see that it has not been wet, moisture being very prejudicial to it. The generality of cotton is white, but some is of a nankeen colour, and is invaluable in the manufacture of that article, as it fades ve y little, even with long use, and frequent washing.

The elasticity of cotton is inconceiveable; it may be pressed into a 50th part of the space into which the strongest packers can reduce it by personal exertion; large screws are erected at many sea-ports where cotton is shipped, for the purpose of bringing the bales into the smallett compass, so as to save freight. Cotton can only be imported as a raw material, in which form it comes to us, from the Levant, the West Indies, South America, and the East Indies. It comes to us without any further preparation than being pretty carefully picked out of the pod, on which it grows, and the seeds separated. Still much dirt, husk, and other impurites remain in it, these are separated by women, at the cotton mills, who pick it over and beat it, with rods to disentangle the knotted parts; this beating is sometimes performed by the machine called a batting machine, or else the cotton is subjected to the opening machine; these processes remove all dirt, dust, and cotton seeds, of which the cotton in its raw state contains a great number, and would be very prejudicial to the operations of the more delicate machines, the cotton when first packed up in the bags is as before stated, compressed very closely for the convenience of stowage, and this condenses it into a hard matted mass, but the batting striking it violently with small sticks, causes the fibres by their natural elasticity, and the motion occasioned among them, gradually to loosen and disengages themselves, and the cotton by repeated strokes recovers all its original volume and is prepared for carding. In the machine which performs this operation, the cotton is exposed to the action of an immense number of loose teeth stuck in leather, in the manner of a brush, these teeth are fixed upon cylinders acting against each other, and the cotton being introduced between them, is combed or carded by the teeth, until almost every individual fibre of the cotton is separated and drawn straight, and every little knotty and entangled part disengaged; by passing gradually through the machine. Being carried from one cylinder to another, the cotton is dispersed lightly and evenly, among the teeth of the whole surface of the last or finishing cylinder, from which it is detached by a curious mechanism in a continued fleece; this is drawn off and contracted, by passing through a funnel, in which the fleece being hemmed in on both sides, is gradually contracted to a thick roll. This may be continued to any length, as long as the machine is supplied with cotton; the roll or band of cotton is drawn off between two rollers, which compress it into a pretty firm flat ribband, called a carding or sliver about two inches broad, which the rollers deliver into a tin can, placed to receive it, and in this it is removed to the drawing frame, which consists of a system of rollers, revolving with different velocities, either from the variation of size in the pairs of rollers, or by their performing a different number of revolutions, in the same space of time, or from both these causes united. Three or more cardings from the carding machine, coiled up in deep tin cans, are applied at once to these rollers, in their passage through which, they not only coalesce so as to form one single drawing, but are also drawn out or extended in length. This process is repeated several times, three four or more drawings as they are now called being united and passed again between the rollers, the number introduced being so varied, that the last drawing may be of a size proportioned to the fineness of the thread, into which it is intended to be spun. By this operation, the fibres of the cotton are drawn out longitudinally, and disposed in an uniform and parallel direction, and all inequalities of thickness are done away, by the frequent doubling or joining of so many different lengths.

The operation of carding effects this in a certain degree, yet the fibres though parallel are not straight, but many of them are doubled, as may easily be supposed, from the teeth of the cards, catching the fibres sometimes in the middle, which become hooked or fastened upon them; but when the carding has been passed 4 or 5 times through the drawing frame, every fibre is stretched out at full length, and disposed in the most even and regular direction, so that each fibre, will when twisted into a thread, take its proper share of any strain the thread may be subjected to. If any crooked fibres are twisted into a thread, they will communicate no strength to such thread, until it is so much stretched, that the crooked fibres become straightened, but before this happens, those fibres which are already extended to their full lengths must be broken.

The fibres of cotton are by these processes, prepared for spinning, but the slivers must first be reduced to a small size, this is done by the roving frame, which like the drawing frame, extends or draws out the sliver, reducing it from a large band to a coarse and loose thread. The roving frame immediately after having drawn and reduced it to the intended size, gives it a very slight twist forming a loose thread which is called the roving, this is the first rudiment of a thread. Although in this state, it is extremely tender, and will not carry a weight

weight of two ounces, it is much more cohesive for its size than before roving, because the twist given it, makes all the longitudinal fibres bind each other together, and compress those which lie athwart. In drawing a single fibre, others are drawn out along with it, and, if we take hold of the whole assemblage, in two places, about an inch or two asunder, we shall find that we may draw it to nearly twice its length, without any risk of its separating in any intermediate part, or becoming much smaller in one part than another. The rovings are now spun into a strong thread, by the spinning frame, which is little more than a repetition of the operation of the roving frame. The roving being drawing out and extended to reduce it to any degree of fineness, and then the proper twist being given, forms it into a firm and strong thread. The strength of this thread depends much upon the perfection of the preparatory processes of picking, carding, drawing, and roving, for as every inch of the roving will meet, with the same degree of drawing, and receives the same twist in the spinning frame, every inequality and fault in the roving, either as to the regularity of its size, or the proper extension of its fibres, will continue in the thread in nearly the same degree.

Such are the processes through which the cotton passes, from the raw cotton, or cotton wool, as imported, to the finished thread. We shall now proceed to enlarge upon each subject, and describe the machinery by which these operations are effected, in the most expeditious and perfect manner; for the explanation of these, we have appropriated two plates, but it cannot be expected that we should, in so limited a work, give a complete account of all the machines used in the cotton manufacture, we can only give an outline of the whole, by detailing the most important of the machines, and content ourselves with verbal descriptions of the others;

First, as the invention of these machines has been the grand source of our commercial greatness, within the last thirty years, it is but right that we should enter into a brief history of the rise and progress of the cotton manufacture, and give due credit to those ingenious men, to whom we as a nation are so greatly indebted, for the original discoveries, and successive improvements upon them.

The spinning of cotton was before the year 1769, performed by hand, a person working at a machine, called a one thread wheel, consisting of a single spindle, put in motion by a wheel and band, turned by the right hand, whilst the thread was managed by the left. This composed the whole of the spinning apparatus, on which one person could with difficulty produce a pound of thread, by close and diligent application in the whole day.

The goods then manufactured were strong and coarse, compared with those of the present day, and little or no thread, finer than from sixteen to twenty hanks in the pound, each hank measuring 840 yards, was then spun. It was subject, as may readily be conceived, to great inequalities, its evenness depending greatly on the delicacy of touch, which the spinner by long habit had acquired, and varied with every little difference, in the extension of the thread during twisting, and the revolution of the spindle in portions of the same length. As the demand for cotton goods increased, various contrivances were thought of, for expediting this part of the manufacture, but though many were very ingenious, none were so successful as to come into general use, until 1767, when the spinning jenny was invented by James Hargreaves, a plain, industrious, but illiterate man, a weaver in the neighbourhood of Blackburn, in Lancashire. The first jenny consisted of eight spindles, all worked together, by a band from one wheel; and the machine was provided with an apparatus, which held all the eight threads at once, in the same manner as the spinner held the cotton, between the finger and thumb. The cotton was at this period prepared for spinning by hand-cards, these were small square boards, upon which a sheet of leather, furnished with wire teeth, was stretched; the carder held one of these in each hand, and putting the cotton between them, they were scraped with one edge over the surface of the other card, in the direction of its teeth; the cotton was then, by a particular manœuvre, removed, and coiled up into short soft rolls, which were called cardings. These were of the thickness of a candle, and from eight to twelve inches long, possessing little strength or tenacity, the slightest force being sufficient to break or pull them asunder. One end of this roll being held between the finger and thumb of the spinner, and the other twisted round the point of the spindle, was rapidly drawn out during its revolution, and formed a coarse soft thread, called a roving. This operation of twisting and drawing was afterwards repeated, and the roving was converted into a smaller, firmer and longer thread. To this operation the term spinning was more particularly applied, the first being considered as preparatory, and was called roving.

For some time after the introduction of the jenny, this mode of roving on the single spindle continued in use, the joining of the carding rendering manual dexterity absolutely necessary. The jenny was soon after its invention enlarged, in the number of spindles to twelve and sixteen, and made such rapid progress, as to alarm the minds of the ignorant and misguided multitude, with the idea, that all manual labour would soon be annihilated by the use of these machines; and they broke into Hargreaves' house and destroyed his machine; this outrage induced him to remove to Nottingham, where he was invited by the stocking weavers, and assisted in the erection and management of a mill, notwithstanding a serious opposition from the lower orders of the people at first. Here the machine was gradually enlarged to thirty, fifty, and eighty spindles, and became very general; but the jealousy of the lower classes of people still continued, and though no scarcity of work had been experienced, they assembled in Lancashire in 1779, and destroyed all the jennies, which worked more than

than twenty spindles; but in three or four years after Hargreaves' first invention, its further extension was stopped by the appearance of a superior mechanic, this was the celebrated Sir Richard, at that time Mr. Arkwright, whose invention and perseverance raised him from the most humble occupation in society, to great affluence and honour; this ingenious gentleman turned his attention to the whole of the manufacture, and indeed his chief improvements were in the preparatory processes. Hargreaves had made a great improvement in carding, by applying two or three cards upon the same stock or handle, and suspending the upper cards, which from their weight and size, would otherwise have been unmanageable, from the ceiling of the room, by a cord passed over a pulley, to the other end of which was affixed a weight or counterpoise. With these, one woman could perform twice as much work, and with greater ease, than she could do before in the common way. The stock cards were soon after succeeded by cylindric cards, the invention of which is claimed by so many different persons, that it is impossible now to determine to whom the merit is due. Among the first who employed them, was the late Mr. Peele, who constructed a carding engine with cylinders, as early as the year 1762, in which he was assisted by Hargreaves. Mr. Peele's engine consisted of two or more cylinders, covered with cards, but it had no contrivance for stripping or taking off the carded cotton. This was performed by two women with hand cards, who alternately applied them to the last or finishing cylinder.

Mr. Arkwright very materially improved this carding machine, by several minor contrivances, but chiefly by the crank and comb. He employed, like his predecessors, two or more large cylinders, covered with cards, revolving in opposite directions, and nearly in contact with each other; they were surmounted with other smaller cylinders covered in like manner, by whose revolutions, in various directions, and with different velocities, the cotton was carded and delivered to the last or finishing cylinder, from which it was stripped off by various contrivances. The cards of the first invented machines were nailed on the stripes or sheets, of six or eight inches broad, and the margin of each sheet in which the nails were driven, being destitute of teeth, formed so many intervals or furrows across the surface of the cylinder. The cotton was stripped off at first by hand, as in Mr. Peele's machine, and afterwards by a fluted cylinder, or by a roller, armed with stripes of tin plate or iron, standing erect like the floats of an undershot wheel, and which revolving quicker than the card, and in close contact with it, scraped off the cotton in distinct portions from each stripe or sheet, which fell into a receptacle below. This was a harsh and rude operation, and injured not only the carding, but the cards themselves.

Mr. Arkwright substituted for the fluted cylinder, a plate of metal, called the comb, finely toothed at the edge, and moved rapidly up and down in a perpendicular direction, by a crank. The slight, but reiterated strokes of this comb, acting on the teeth of the cards, detached the cotton in a fine uniform fleece. On the finishing cylinders also, narrow fillet cards, as they are termed, wound round in a spiral form, were substituted by Mr. Arkwright for the ordinary cards, nailed across. The continuity of the fleece was thus preserved, which was destroyed before, by the intervals or furrows, to which we have alluded, and being gradually contracted in its size, by passing through a kind of funnel, and flattened or compressed between two rollers, was delivered into a tin can, in one continued, uniform, perpetual, carding, so long as the machine was kept in motion, and was supplied with the raw material.

But Mr. Arkwright's grand improvement was the invention of preparing the cotton by rollers; it is essential to good spinning that the fibres shall be disposed exactly parallel to each other, which is effected by drawing out or extending the mass of cotton, by certain parts, resembling the fingers and thumb of the spinner; the contrivance for this purpose consisted of a certain number of pairs of cylinders, each pair revolving in contact with its fellow. Suppose then that a loose thread, or lightly twisted roving of cotton, was made to pass between one pair of cylinders, properly adapted with a facing for holding it, and that it proceeded from thence to another pair, whose surfaces revolved with a much greater velocity; it is evident, that this quicker revolution would draw out the cotton, and render it thinner and longer when it came to be delivered on the other side. This is the operation which the spinner performs with his finger and thumb; and if the cotton be delivered in this state to a spinning apparatus, it will be converted into thread.

The immediate spinning apparatus, or that part which gives twist to the thread, was made by Mr. Arkwright, on a totally different principle from the jenny. He employed the spindle of the old flax wheel, which was used for those substances, whose fibres, from their nature, but more particularly from their length, would not admit of the preparatory process of carding. Their fibres were dressed and disposed in an even and parallel direction, by an operation resembling combing, and were then coiled round the head of the distaff, affixed to a wheel, furnished with a spindle, bobbin, and fly. The fly and spindle moved together, and were kept in rapid motion by a wheel and band, worked by the foot of the spinner. The bobbin which received the thread, ran loose upon the spindle, and moved only by the friction of its ends, in proportion as the fibres of the flax were disengaged from the distaff, by the finger and thumb of the spinner, and were twisted by the fly. If we suppose the machine itself to be left at liberty, and turned without the assistance of the spinner, the twisted thread being drawn inwards by the bobbin, would naturally gather more of the material, and form an irregular thread, thicker and thicker, till at length the difficulty of drawing out so large a portion of the material, as had acquired the twist, would become greater than that of snapping the thread, which would accordingly break. It

It is the business of the spinner to prevent this, by holding the material between the finger and thumb, and by separating the hand during the act of pinching, that the intermediate part may be drawn out to the degree of fineness previous to the twist.

To accomplish these purposes by machinery, the object of Mr. Arkwright's invention, two conditions became indispensably necessary,

1st, that the raw material, should be so prepared, as to require none of that intellectual skill, which is alone capable of separating the knotty or entangled parts, as they offer themselves. And, 2dly, that it should be *drawn out*, by certain parts, resembling the finger and thumb of the spinner. The first of these was completely fulfilled by the various machines and contrivances for the preparation of cotton for spinning, which Sir Richard afterwards invented, and obtained a patent for; the second was accomplished in his first and capital machine, since called the twist or Water Frame. He contrived to make the rotary carding and spinning engines, to move by horse, by water, and by steam; and thus by saving of labour, and with the advantage of a patent monopoly, he was in a few years rendered one of the most opulent of our manufacturers.

Mr. Arkwright also applied his invention of the rollers, to other parts of the process, viz. the preparation of the cotton immediately after carding, to obtain the greatest equality of thickness and parallelism of the fibres, by the drawing frame which we have before described. He had many difficulties to struggle with, in bringing these inventions, and improvements to perfection; he first attempted to put his ideas in practice at Liverpool, but not receiving proper encouragement, he entered into partnership with Mr. Smalley, of Preston, in Lancashire, but their property failing, they went to Nottingham, and there by the assistance of wealthy individuals, erected a considerable cotton mill, turned by horses; but this mode of proceedure was found too expensive, and another mill on a larger scale was erected at Cromford, in Derbyshire, in the year 1771, the machinery of which was put in motion by water. This mill is still at work, and deserves notice as being the first of those numerous establishments, which were very quickly erected in various parts of the country; and the manufacture being thus firmly established, Mr. Arkwright's claims to the inventions were disputed, and his patent right contested in the Court of King's Bench, and after much litigation between him and a host of opulent manufacturers, who had now entered into the business, the letters patent were cancelled on the ground, of his not being the original inventor. The court entered into the examination of the origin of every idea, and the assistance he derived, from every one of his workmen; but upon the whole, without minutely detailing further particulars, it appears that cotton spinning was no new attempt when Mr. Arkwright embarked in it; but many difficulties occurred in bringing it to perfection, and in his hands the carding and spinning of cotton, became a national manufacture. According to his statement, it appeared that the advancement of it, during a period of five years, cost him, and those that were concerned with him, 12,000*l.* before they derived from it any profit, and it must be allowed that he alone had sufficient perseverance, activity, and skill, to perfect a scheme, in the prosecution of which many others had failed, and to render it valuable to himself and the public. It appeared on the trial, that Mr. Arkwright certainly received many ideas from Mr. Kay, a clockmaker of Warrington, who was in some way concerned with him in making the first machines; but in justice to the memory of Arkwright, it must be stated, that the higher praise of completing the invention, of bringing it to its present state of perfection, and making it a grand instrument of national prosperity, was exclusively his own. He who suggests a new and important principle, has only advanced one step into the field of discovery, and has a claim upon the liberality of his country, and the grateful recollections of posterity; but he who pursues it through all its ramifications, exhausts all its resources, and extends it to all the purposes, to which it is applicable, has certainly performed a task far beyond the powers of the original inventor. Such are the relative merits of Mr. Kay and Mr. Arkwright. This truly eminent man, at the same time that he was inventing and improving machinery, was also engaged in other undertakings, which any person, judging from general appearance, must have pronounced incompatible with such pursuits. While he was taking measures to secure to himself a fair proportion of the fruits of his industry and ingenuity, he was extending the business on a large scale; he was introducing into every department of the manufacture, a system of industry, order, and cleanliness, till then unknown in any manufactory where great numbers of people were employed together, but which he so effectually accomplished, that his example might be regarded as the origin of all similar improvements. The merits of Sir R. Arkwright may be summed up with observing, that the object in which he was engaged was of the highest public value; that though his family were enriched by it, the benefits which have accrued to the nation have been incalculably greater; and that upon the whole he is entitled to the respect and admiration of the world. He was knighted by His Majesty in 1786, and died in August 1792 at his princely mansion near his mills at Crumford; report says, he left a property of more than half a million of money in value, though he began the world as only a country hair-dresser.

The system of spinning introduced by Sir Richard, was found most particularly applicable to the production of thread for warp, or stocking yarn, whilst the Jenny of Hargreaves, was chiefly employed in spinning the woof or weft, for the coarse kinds of which it is better adapted than the perfect machine which Sir Richard invented. The jenny for some years after its introduction spun all the twist and weft in the kingdom, the use of this machine has however since been almost superseded by a third machine called a mule, for the invention of which we are indebted to the ingenuity of Mr. Samuel Crompton of

of Bolton, who lately (1812) received a reward of 5,000*l.* from parliament, it appearing that he had derived but little benefit from the invention. The mule was invented about the year 1776, during the term of Sir Richard's patent right, and did not on that account come into general use till after its expiration; it is a compound of the two machines of Arkwright and Hargreaves, and is considered as its name imports, the offspring of the twist frame and jenny. It consists of a system of rollers like those of the twist frame, through which the roving is drawn and received upon spindles, revolving like those of the jenny, and from which it acquires the twist. The carriage on which the spindles are disposed is moveable, and receding from the rollers somewhat quicker than the thread is delivered, draws or extends it in the same manner as is done by the jenny.

This completes the series of machines now in use, and is the only very important discovery in spinning since the inventions of Sir R. Arkwright, on which indeed its chief merit is founded. Of its excellence, and also of those other machines employed in the different preparatory processes, some idea may perhaps be formed, when it is stated that a pound of fine cotton has been spun on the mule into 350 hanks, each hank measuring 840 yards, and forming together a thread 167 miles in length.

DESCRIPTION OF THE MACHINES.

The picking of cotton is necessarily performed by hand, as it requires a discretionary power, which a machine cannot possess. This department is therefore conducted without the aid of mechanism. The batting is the first machine the cotton passes through; here the cotton is spread by women upon a platform, which is in constant motion, from one end of the machine to the other, and therefore carries the cotton along upon it, and in its passage it receives the strokes of several small sticks, or rods, which alternately beat upon it with a very sharp stroke. This platform is formed of a long cord, which is repeatedly passed over two rollers, one of which is supported at one end of the frame, the other is at the opposite end; the cord passing round from one of these to the other 20 or 30 times, and having all the turns made parallel to each other at about an inch asunder, forms an horizontal platform for the support of the cotton. Whilst it is under the operation of the batting, one of the rollers is kept in constant motion by the train of wheel-work which receives its motion from the main spindle of the machine; by these means the endless rope, which extends from one roller to the other, and forms the platform for the cotton, is in constant motion, and the cotton which is laid upon it at one end traverses slowly to the other, receiving in its passage the blows of the batting rods, which strike upon it alternately. Their action is produced in a very curious manner, being attached by joints to the upper ends of the vertical lever, which, by means of cranks upon the main spindle, have an alternating motion to and from the platform. The rods are attached to their levers by a short spindle, upon which they move as on an axis, and have pulleys fixed at the side of them, which, by straps fixed to the framing at one end of each, and to the circumference of these pulleys at the other ends, turn the pulleys and rods over at the same time that they advance to and recede from the platform by the motion of the levers to which they are attached; thus the motion of the rods exactly imitates the action of the arm of a person beating the cotton with a small cane, for the vertical levers just mentioned may be considered as the motion of the arm on the joint of the shoulder, drawing the cane backwards when it is lifted up on the elbow joint as a centre to fetch a stroke, and advancing while it is falling to make the stroke; let the joint of the levers with the rods represent the elbow joint, and the operation of the movement is the same. The machine has four rods on each side, which act alternately with great rapidity, and the whole movement is regulated by a fly wheel. The batting machine, though not a leading one in the cotton manufacture, is of important use in saving labour and beating the cotton in a very regular manner, for no part can escape its action.

The machine called a devil, or more properly the opening machine, is used for similar purposes as the batting machine, though it is not to be considered as one of the same series, being used for the coarser sorts of cotton in the same stage as the batting engine is used for the finer sorts.

It consists of a large cylinder, put in rapid motion by an endless band passing round a pulley upon its axis. This cylinder has a great number of teeth fixed into its periphery, and the hood or casing which encloses it contain a set of similar teeth, or spikes, fixed within side of it, and situated very near the spikes of the cylinder as they revolve. The cotton enters into the machine between a pair of fluted rollers, which are placed immediately above each other just before the cylinder, a heavy weight being suspended from the pivots of the upper roller causes them to press together with a sufficient force to draw the cotton in between them, and the flutes or indentions of the two rollers mutually locking into each other, they take the cotton the more certainly. The lower roller is turned round by means of wheel-work from the main spindle; the cotton is spread out upon an endless feeding cloth, strained between two rollers, one of which works very close to the fluted feeding roller, and is turned round thereby, so that the cloth, and the cotton spread out upon it by children are kept in constant motion towards the cylinder, and delivers the cotton between the feeding roller. These give it regularly to the cylinder, which is rapidly revolving, and its teeth take the cotton and carry it round between the cylinder and the hood, working it between their teeth to open and unravel every knot or tuft of cotton. After passing through the machine, the cotton is thrown out finished, having been opened in every part so as to completely disentangle it; and the dust, cotton seeds, or any other extraneous matter

matter drop out through a wire grating, which encloses the lower half of the cylinder and prevents the escape of the cotton until it has passed quite round it. Some of the most improved mills use opening machines, which are provided with two cylinders revolving against each other, so that they resemble two of these machines put together, by which means the cotton is more completely worked in passing through them.

Carding-machine.—This we have before described, in general terms, to consist of a number of cylinders covered with wire teeth; but for its more particular explanation we must refer to *Plate* I. *Fig.* 1, which is a section: here B B is a large cylinder turned rapidly round by an endless strap on the pulley A; the surface of the cylinder is covered with cards, the sheets of leather for which are glued or nailed on in stripes or sheets parallel with its axis, and disposed in such a direction that when it revolves in the direction of the arrow the teeth upon it go with their points forward, so that if a lock of cotton was held against them, it would be drawn inwards upon the teeth. The cylinder revolves under an arch *c c*, lined with the same kinds of cards which are shewn in *Fig.* 2.; the teeth are disposed to meet those of the cylinder. D is a second cylinder of cards, the teeth meeting the first, its motion being taken by a large bevelled wheel *f*, on the end of its spindle from a small pinion on the end of an inclined axis *r*, which at the other end receives its motion by a pair of equal bevel wheels from the spindle of the great cylinder B B. Before the cylinder at *b*, are a pair of fluted feeding rollers, between which the cotton passes, and is delivered to the cylinder, the cotton is spread out upon a feeding cloth *e* which traverses constantly round two rollers *g h*, one of which is turned by means of a pinion from the feeding rollers; these receive their motion from a wheel on the end of the cylinder D by means of bevil wheels, and an inclined spindle not seen in the figure, but its direction is shewn by the dotted line *a a*. The cotton is taken off the cylinder D in a continued fleece by the mechanism described in *Figs.* 1 and 3, which is called the comb, or taker off. This is a rod or iron bar *i i*, situated parallel to the axis of the cylinder, and cut on the lower edge with fine teeth like a comb; it rises and falls parallel to itself by being united to two rods *k*, which are guided by two levers *l l*; the lower ends of the rods *k k* are, as shewn in *Fig.* 1. jointed to two small cranks *m* formed on a spindle which is turned by a pulley *n* with an endless strap from a pulley fixed on the main axis close behind the great pulley A. Now by the motion of these cranks the rod *i i* rises and falls, and at the same time moves a little to and from the surface of the cylinder D. By this motion it scrapes downwards between the teeth thereof, and in consequence removes the cotton from them the whole length of the cylinder at once, and the motion of the crank is so quick, that by the time this piece of cotton so detached from the great cylinder D, has moved with the cylinder as much as its own breadth, the crank makes another stroke, and in consequence the second piece detached from the teeth, adheres to the first, the third adheres to the second, and so on. The cotton is thus stripped, or skinned off the cylinder, in a continued and connected fleece. This fleece, as is shewn in *Fig.* 1, is received upon a plain cylinder E, which is turned slowly round, by means of pulleys and a band from the pulley dotted round the centre of the cylinder D. F is a small roller gently pressing upon the fleece, to make it lap evenly upon the surface of the cylinder E, as the same turns round, and takes it up when stripped off the surface of the cylinder D.

G is the main drum, or wheel, which turns the machine; it is fixed on a spindle extending the whole length of the mill, being suspended by brackets like *o* from the ceiling, and turning forty or fifty machines in a row.

I K, *Fig.* 1, are two small cylinders called urchins, they are covered with cards and revolve, so that their teeth act with the teeth of the great cylinder, through proper openings left between the top bars or rails, composing the arch CC; the urchins are turned slowly round in the direction of the arrows, by means of a band *x x* from a wheel on the spindle of the cylinder D.

To explain the action of this machine, we must give some idea of the nature of the operation of carding; the card may be compared to a brush, made with wires instead of hairs, stuck through a sheet of leather, the wires not being perpendicular to the plane, but all inclined one way, in a certain angle, see fig. 2, where R and S are these sheets of leather for a pair of cards, and TT, or VV, represent the teeth or card wires respectively belonging to each. Beneath is a view of one wire insulated, shewing the two teeth, with their bend in the shank, called the knee bend, by which they are inclined to the leather, in the manner before mentioned. Now we may conceive, that cotton being stuck upon the teeth of one of these cards, another may be applied to it, and combed or scraped in such a direction, as to strike the cotton inwards upon the teeth, rather than tend to draw it out. Of the consequences of a repetition of the strokes of the empty card in this direction, upon the fall, one is a more equable distribution of the cotton, upon the surface of the teeth, and in doing this the fibres are combed and laid straight. Then, if one card be drawn in an opposite direction over the other, it will, in consequence of the inclination of its wires, take the whole of the cotton out of the card, whose inclination is the contrary way.

The cotton being spread out evenly upon the feeding cloth *e*, and advancing with the cloth, it is thrown in between the fluted feeding rollers *b*, which deliver it gradually and equally to the cylinder, by this it is carried round until it meet the urchin I, which is turning round very slowly, and its teeth meeting the teeth of the great cylinder, take off part of the cotton therefrom, and carry it round till it meets K, which moves so as to take the cotton off from I, and return it again to the great cylinder. The object of thus transferring it, is to obtain a more regular and equable distribution, than the feeding

ing or spreading the cotton upon the cloth *e*, will make upon the cylinder. The great cylinder thus receiving the cotton, carries it round and cards it against the teeth lining the arch CC; in this process it becomes more equably distributed over the teeth in the cylinder, and gets carded; in so doing the cotton continues in this manner, hanging sometimes in the teeth of the cylinder, and sometimes in those of the arch, but slowly advancing till it comes to the cylinder D, whose teeth meeting those of the cylinder, and turning round very slowly take the cotton from it in a very regular and even film spread over its whole surface. This film it carries round to the comb *i*, by which it is detached, as before described, and lapped round the cylinder E, which continues to lap up the fleece upon it, until it has made fifteen or twenty turns, and of course as many revolutions of the fleece round its circumference. The attendant then breaks it off; by dividing it at one part and spreading it out straight, it will form a fleece called a lap, which is the length of the circumference of the cylinder, and consisting of fifteen or twenty thicknesses. By this admirable contrivance great regularity is obtained in the thickness of the lap, because, if at any one part, the fleece produced by the machine is thinner or thicker, than it ought to be, in consequence of any irregularity in the spreading of the cotton wool upon the cloth, previous to carding, such irregularity will have no sensible effect upon the ultimate thickness of the lap, because it is composed of thirty or forty strata, and there is no probability that the inequalities of these several strata will fall beneath each other, but every chance that they will be equally dispersed through the whole, and thus correct each other. The lap when taken off, is laid flat on a cloth, with which it is rolled up and conveyed to a second carding machine, and spread out upon its feeding cloth; in this machine it undergoes exactly the same operation as in the first, and the fleece is detached from the cylinder D in the same manner, but instead of going to the lapping cylinder E, as we have described, it is gathered up as shewn at X in fig. 3, into a tin funnel marked *p*'; it then passes between a pair of rollers *q r*, which compress and flatten the fleece in its contracted state, into a pretty firm, and connected sliver or band Y, and deliver it into a tin can. The lowest of these rollers *r* is situated upon a spindle *s*, extending across the frame, and turned by a pulley *t* upon the end of it, which is connected by an endless band, with the pulley *z* upon the spindle of the cylinder D.

By these means, the fibres of cotton are disentangled from all knots, and the whole is reduced from the entangled and matted wool, to a regular and equable sliver or band, which is conveyed away in the tin can, to the drawing frame, which we shall next describe by the help of fig. 5, which is a section of the operative part of the machine, taken through its middle; EEEE represent four of the perpetual slivers or endless cardings we have just described, entering into it; let A represent the section of a roller, whose pivot does not turn, in a pivot hole, but in the bottom of a long narrow notch B, cut in an iron standard; *a* is the section of another iron roller, whose pivot is retained in the same notches at each end, while the roller itself lies or rests on the roller A, below it. The surfaces of these rollers are fluted lengthwise like a column, only the fluting are very small and sharp, like deep strokes of engraving, very close together; it is plain, that if the roller A be made to turn slowly round its axis, by machinery, in the direction as expressed by the dart; the roughness of the flutings will take hold of the similar roughness of the upper roller, and carry it round also in the direction of the dart, while its pivots are engaged in the notches B, which they cannot quit. If, therefore, we introduce the end F of the cotton sliver, or band EF, formed by the carding machine, it will be pulled in by this motion, and will be delivered out on the other side, considerably compressed by the weight of the upper roller *a*, which is of iron, and is also pressed down by a piece of brass, which rests on its pivots, or other proper places, and is loaded with a weight C. There is nothing to hinder this motion of the riband thus compressed between the rollers, and it will therefore be drawn through from the cans. The compressed part, after passing through, would hang down and be piled up on the floor as it is drawn through; but it is not permitted to hang down in this manner, it is brought to another pair of sharp fluted iron rollers, K and L. Supposing this pair of rollers to be of the same diameter, and to turn round in the same time and in the same direction with the rollers A, *a*, it is plain that K and L would drag in the compressed riband and would deliver it on the other side, still more compressed. But the roller K is made, by the wheel work, to turn round more swiftly than A. The difference of velocity at the surface of the rollers, is, however, very small, not exceeding one part in twelve or fifteen. But the consequence of this difference is, that the skein of cotton will be lengthened in the same proportion; for the upper roller pressing on the under ones with considerable force, their sharp flutings take good hold of the cotton between them. Since K and L take up the cotton faster than A and *a* deliver it out, it must either be forcibly pulled through between the first roller, or it must be stretched a little by the fibres slipping among each other, or it must break.

When the extension is so very moderate as we have just now said, the only effect of it is merely to begin to draw the fibres, (which at present are lying in every possible direction) into a more favourable position, for the subsequent extensions.

The fibres being thus drawn together, the cotton is introduced between a third pair of rollers O P, constructed in the same way, but so moved by the wheel-work, that the surface of O moves nearly, or full three times as fast as the surface of K, the roller P being also well loaded, they take a firm hold of the cotton, and the part between K and O is nearly or wholly trebled in its length, or the sliver is extended to almost four times the length, in which it enters between *A a*. After the sliver

sliver has passed through the three pairs of rollers it is conducted through a tin funnel H, being drawn forward, by a pair of rollers R S, this contracts it into a regular sliver, and it is delivered at G into a can. The upper roller S, is merely pressed down upon the under one by its own weight, and therefore compresses it but little, though sufficiently together with the contraction, produced by the funnel H, to unite the four slivers EEEE, which enter together into one which passes out at G, between the rollers RS. These rollers do not draw or extend the cotton; their velocities being accurately adapted to take up the four slivers as fast as they come through the other pairs, and by drawing them all together through the funnel H, to unite the four into one, and the slight pressure of the rollers compresses them into a firm and connected sliver, which though compounded of four, is only the same size as any one of the four put in, because it is drawn out to four times the length. The effect of the machine has only been to straighten and lay the fibres parallel to each other; for the motion which the drawing produces among them always tends to extend each individual fibre to its full length, and it is necessary to unite several slivers together, or the drawing would reduce the sliver to such a small size, that it would not bear sufficient extension without separating and breaking across.

Figs. 4 and 6 explain the wheelwork, which communicates the motion from one roller to the others, *Fig.* 4 being a view of the wheel-work at one end of the rollers, and *Fig.* 5 the wheels at the opposite end. The motion is given to the whole machine by a strap and pulley D, *Fig.* 5. on the end of the pivot of the roller O. On the opposite end of this roller, the small wheel *g*, *Fig.* 6, is fixed and turns *h*, which is mounted only on a stud, and carries with it a pinion *i*, this turns a wheel *k*, on the end of the pivot of the roller K; now as the wheel *g* is larger than *h*, the latter will move much slower, and as *i* is smaller than *k*, this will move slower than either; the proportions are so adapted, that K and *k* will only turn once for three times of O *g*, but the proportions vary in different mills. On the other end of the roller K, a pinion *f*, *Fig.* 4, is fixed, this turns an intermediate or connecting wheel *e*, and thus gives motion to the wheel *d*, fixed on the end of the roller A, which has the roller *a* over it; now the wheel *f* being, in its diameter and number of teeth, to *d* as twelve to fifteen, of course the relative velocities of the rollers A and K will bear that proportion as before stated.

The rollers R S are turned by means of a strap, from a pulley on the pivot of the front roller, O.

The reader will by this perfectly comprehend Sir R. Arkwright's great principle of cotton spinning, by, viz. the drawing by rollers, which extends the fibres in so perfect a manner.

As the drawing frame takes in four slivers E E E, and draws them into one at G, this is repeated four times over, by passing the sliver as many times through the machine; therefore, by this process the sliver is drawn out ($4 \times 4 = 16 \times 4 = 64 \times 4 = 256$) to 256 times the original length, as produced by the carding machine.

In this state the sliver presents a most beautiful appearance, being so extremely regular in its size, and all the fibres being drawn so straight, that it bears a beautiful glossy or silky appearance. After this preparation of the sliver it must be reduced in size to a small thread, this is done at two operations, the first called roving, and the next spinning. The general effect of the spinning process is, to draw out this massive sliver, and to twist it as it is drawn out; but this is not to be done by the fingers pulling out as many fibres of the cotton at once, as are necessary for composing a thread of the intended fineness, and continuing this manipulation, regularly across the whole end of the riband, and thus as it were nibbling the whole of it away. The fingers must be directed, for this purpose by an attentive eye; but in performing this by machinery, the whole riband must be drawn out together and twisted as it is drawn; this requires great art and very delicate management, it cannot be done at once, that is, the cotton sliver cannot be first stretched or drawn out to the length that is produced; from the tenth of an inch of the sliver, and then twisted. There is not cohesion enough, for this purpose it would only break off, a bit of the sliver and could make no further use of it, for the fibres of cotton are very little implicated among each other in the sliver, because the operation of carding and drawing has laid them almost parallel, in the sliver; and though compressed a little by its contraction in the card, from a fleece of twenty inches to a riband of two, and afterwards compressed between the rollers of the drawing frame, yet they were so slightly that a few fibres may be drawn out without bringing many others along with them. For these reasons, the whole thickness and breadth of two or three inches, is stretched to a very minute quantity, and then a very slight degree of twist is given it, viz. about two or three turns in the inch, so that it shall now compose an extremely soft and spungy cylinder, which cannot be called a thread or cord, because it has scarcely any firmness and is merely rounder or slenderer than before being stretched to about thrice the former length. This is called a roving, and the operation is performed in the roving frame which is shewn in *Figs.* 7, 8, and 9, the first being a front elevation, and the other a cross section, the reduction of the sliver is affected by rollers in the same manner as the drawing frame, but only two ends being put through together, instead of four, the size is of course reduced: but this reduction renders it so delicate, that it is necessary to give it a slight twist to render it sufficiently cohesive to bear handling.

The machine contains three heads or frames *AA* of rollers, each of which receives four ends or slivers from the can, BB *Fig.* 8, which are those brought from the drawing frame, and enter between the back rollers *a*, and are drawn out from the cans between them, and the other rollers *b* to the proper degree of fineness, but which varies with the quality of the yarn which is to be spun.

spun. Each of the slivers after passing through the rollers, is received into a tin can D, through a small funnel E, at the mouth of which the can is set up in a frame *d d e f*, called the skeleton. It is supported on a pivot at bottom, and is kept in rapid motion by a band, working on a pulley fixed at the bottom of the skeleton; the neck of the funnel E, is guided by a collar to keep the whole steadily upright, as it revolves. The rollers of this machine act in the same manner as those of the drawing frame, but have only two pairs of rollers instead of three; they are turned round by means of contrate wheels *g*; on the end of each, which are worked by pinions on the tops of as many vertical spindles *k*, which at their lower ends have pulleys turning the skeletons, by means of bands; the spindles *k* are turned round by a strap *l* which passes round and is common to all when the machine is ever so long, the strap receives its motion, by passing round the drum F, the spindle G of which is turned by the mill, the drum also receives other straps as at *m*, to turn other frames in different directions; I is the sliding coupling box, by which the drum can at any time be detached from its spindle, raising it by the lever K, and then its points do not touch. The arms of the drum, which being fitted on a round part of the spindle does not turn with it, but on letting down the box I, which is fitted on a square, it is put in motion, and also the other machinery. By a similar contrivance any one of the spindles *k* can be detached, and the two skeletons which it turns will then stand still while the cans D are removed.

The manner of action in this machine is easily gathered from the description, the slivers pass two together, through the rollers, and are reduced or drawn out therein to the proper degree of fineness; then falling into the funnels E, of the revolving cans, they are by the rapid motion thereof twisted round; because the centrifugal force disposes the cotton to lay round the inside of the can in a regular coil, forming as it were a lining of cotton, to the whole of the interior surface; and by this means the end of the roving becomes in a manner attached to the can, and is twisted round by its motion so as to form a coarse loose thread with a very slight twist, and a very soft and open substance. Such is the state of the roving as prepared by the roving frame. All the preceding processes are to be considered as the preparation; and the operation of spinning is not yet begun. These preparations are the most tedious, and require more attendance and hard labour than any subsequent part of the business. For the slivers from which the rovings are made, are so light and bulky, that a few yards only can be piled up in the cans set to receive them from the carding and drawing. A person must therefore attend and watch each roller of the drawing and roving frames to join fresh slivers as they are expended. It is also the most important department in the manufacture; for as every inch will meet with precisely the same drawing and same twisting in the subsequent parts of the process, therefore, every inequality and fault of the sliver, indeed of the fleece as it quits the finishing card, will continue through the whole manufacture, in a greater or less degree, being only diminished not corrected by the drawing, doubling, &c. It is evident that the roving produced by these operations must be exceedingly uniform; the uniformity really produced exceeds all expectation; for even although there be some small inequalities in the carded fleece, yet these are not matted clots, which the card could not equalize, and only consist of a little more thickness of cotton in some places than in others. This inequality will first be diminished by the lapping of the fleece in the breaking card; and when such a part of the sliver comes to the first roller of the drawing frame, it will be rather more stretched by the second. That this may be done with greater certainty the weights of the first rollers are made very small, so that the middle part of the sliver can be drawn through while the outer parts remain fast hold.

As a preparation for spinning, the rovings must be wound upon bobbins from the cans D of the roving frame, which are taken away from the skeletons as soon as they are filled, and carried to the winding machine, *Fig.* 10. which however only shews the operative parts of the machine, the frame being omitted. The chief part of it is a cylinder A, which is turned round by a winch handle B; the bobbins *a a* on which the rovings *b b* are to be wound rest with their weight upon the surface of this cylinder, and are carried round by it with great rapidity, and wind up the rovings, which are guided by pins projecting from a rail *d d*, which has by the machine a slow traversing motion from one end of the bobbing to the other, and thus lays the cotton regularly on the whole length. The bobbins are merely put loosely on a wire *e*, and can quickly be changed for others when they are filled, they are then carried to the spining frame *(see Fig.* 11 *and* 12. *of Plate II.)* the former being a front view and the other a side section. In both of them, A represents the bobbins filled with rovings which is to be spun into thread; they are set up in a rack or frame over head, and are conducted down at *a a* through rollers *b c d*, which are the same as the drawing frame, and extend it in length 10, 12, or 16 times, accordingly as the yarn which is to be spun requires to be finer or coarser. This is delivered out to the spinning apparatus or spindles: these are straight steel arbors, on the lower end of which the pulleys, or hafts as they are called, receive the bands *f* for turning them. These spindles are mounted in a frame common to them all, which consists of two rails B C, the lower one supporting the points or toes of the spindles, and the other having bearings for the cylindrical parts of each spindle, and a wire staple is fixed over each to keep them up to their bearings. Above this bearing the spindle is only a straight cylindrical wire, and on the upper end of it the fork or flyer *h* is fastened either by screwing it on, or it is stuck fast on by friction, which is sufficient to carry it about. The two arms or branches of the flyer are sufficiently distant for them to revolve round clear about the bobbin *k*, which is fitted loosely upon the cylindrical spindle, and with liberty to slide freely

freely up and down upon it. The weight of the bobbin is supported by resting on a piece of wood attached to a rail M, which has a slow rising and falling motion, equal in extent to the length of the bobbin between its shoulders, by which means the thread as it comes through the eye, is formed at the ends of either of the branches *h* of the flyer, and is wound by the motion thereof upon the bobbin. It becomes equally distributed throughout its length, giving it a cylindrical figure instead of keeping all the thread at one part like a barrel, as would happen if the bobbin did not rise and fall. The spindles are constantly kept in rapid motion by the machine, and twist the fibres round each other the instant their ends come out, before the rollers leave the other ends, or they would fall to pieces; being drawn out so fine, that the cohesion of the fibres is insufficient to bear any thing, and the twist given to the roving is entirely lost; for it was at first only one turn in one or one and a half inches in length, and this one and a half inch being by the draught of the rollers drawn out 10 or 12 times the length, the twist of one turn in this length is imperceptible, and adds no strength whatever to the roving, so that it is necessary the spindle should by the connexion of the thread passing down from the rollers to its flyer, give a twist to the fibres the instant they come through the rollers, which they do by the thread being conducted down from the rollers through the eye formed at the end of either of the branches of the flyer, which revolves with the greatest rapidity along with the spindle, and then gives the twist to the thread; the bobbin does not partake of the motion of the spindle, but is retained by the friction of its lower end resting on the piece of wood *l*, and this is increased by a washer of leather put under it. This friction gives such a resistance to the motion of the bobbin, that the motion of the flyer running round it will lay the thread evenly upon it as fast as the rollers suffer it to come forwards.

The motion of the whole machine is communicated in the same manner as the roving frame by a vertical spindle D to a drum E which receives a strap *n* for one frame, and a similar one *o* for another. The former of these straps extends the whole length of the machine, turning all the vertical spindles *p* on both sides of the frame by means of pulleys on the lower ends of them. Each of these vertical spindles puts in motion four spindles and the rollers belonging to them; the former by the bands *f*, which go round the wheel *r* upon the spindles *p*, and the rollers it turns by a pinion at the top of each, turning a contrate or face wheel *t* on the end of each roller.

It is to be observed that the frame, *Fig.* 11, is in practice extended to contain 40 or 60 spindles on each side instead of four, and one of the vertical spindles *p*, is provided for every four spindles, but the strap *n* is common to them all. The wheelwork for turning the rollers is shewn in *Fig.* 13, and needs no explanation, being the same with those already described. The rise and fall of the rail *m*, and all the bobbins upon it, is thus produced; they are both suspended from the opposite ends of a horizontal lever L L M, which has a third arm M proceeding from it, which bears against the surface of a part N, which is a wheel of that figure turning slowly round, and thus moving the lower L L M and producing an alternate rise and fall of all the bobbins in the frame. The heart is turned round by a wheel R, *Fig.* 11, on the end of its spindle worked by a pinion upon a spindle S, which also carries a wheel T, and this is turned round by means of a worm cut upon the main spindle of the frame.

The drum can at any time be detached from its spindle, and then the whole frame will stand still; for this purpose the spindle D passes through the drum E, a circular fitting, so that it slips freely round within it without giving motion to the drum, except when it is cast into gear; this is done by two locking bolts *w*, shewn by dotted lines passing through the drum, and both fixed into a collar or socket *x*, fitted to slide up and down the spindle. It has a groove formed round it, in which a fork at the end of a lever is received, so that the forked lever embraces the piece *w* in the groove, and when lifted up raises the two locking bolts with it, and unlocks the drum from the spindle D by withdrawing the locking bolts from their contact with an arm *f*, which is fixed fast on the spindle beneath the drum, and therefore turns with it; but the locking bolts being let down that their ends may project through the drum and intercept the cross arm *f* of the spindles, the drum and all the machinery is put in motion. In like manner each of the pulleys of the vertical spindles *p* which receive the great strap *n* are fitted to slip round on their spindles *p*, but can at any time be united thereto to give them motion by a locking box bayonet *z*, which is cast in or out of action at pleasure by a small lever in exactly the same manner as the locking of the principal drum; therefore by this lever any four spindles can be detached from the machine at pleasure, and their motion stopped to change the bobbins when they are filled with thread, which is then finished, and requires only to be reeled off the bobbins for the weaver or other purpose.

From this account it appears that the process of spinning differs but very little from the roving, except that the twist given after its last stretching in length is so much greater than the roving, being intended to give the yarn hardness and firmness, so that it will afterwards break rather than stretch any more. The perfection of the ultimate thread or yarn depends in a great measure on the extreme softness of the roving, for it is this only which makes it susceptible of an equable stretching; all the fibres yielding and separating alike, and this property will be greatly influenced by the quantity of twist given by the roving frame; for these points no very distinct rule can be given. It is various in different mills and with different species of cotton wool, as may be easily imagined. The immediate mechanism or manipulation must be skilfully accommodated to the nature of that friction which the

fibres of cotton exert on each other, enabling one of them to pull others along with it. This is greatly aided by the contorted curled form of a cotton fibre, and a considerable degree of elasticity which it possesses. In this respect it greatly resembles woollen fibres, and differs exceedingly from those of flax; and it is for this reason that it is so extremely difficult to spin flax in this way; its fibres become lank, and take any shape by the slightest compression, especially when damp. But beside this, the surface of a cotton fibre has a harshness or roughness which greatly augments their mutual friction. This probably is the reason why it is so unfit for lint and other dressing for wounds, and is refused by the surgeons even in the meanest hospitals. But its harshness and elasticity fit it admirably for the manufacture of yarn. Even the shortness of the fibre is favourable; and the manufacture would be very difficult if the fibre were thrice as long as it generally is. If it be just so long that in the finished thread a fibre will rather break than come out from among the rest, it is plain that no additional length can make the yarn any stronger, with the same degree of compression by twining. A long fibre will indeed give the same firmness of adherence with a smaller.

This would be an advantage in any other yarn; but in cotton were it less it would become woolly and rough by the smallest use, and it is already too much disposed to teazle out. Now, suppose the fibres much longer, some of them may chance to be stretched along the sliver through their whole length. If the sliver is pulled in opposite directions, by pinching it at each end of such long fibres, it is plain that it will not stretch till this fibre be broken up, or drawn out; and that while it is in its extended state, it is acting on the other fibres in a very unequable manner, according to their positions, and renders the whole apt to separate and draw more irregularly. This is one great obstacle to the spinning of flax by similar machinery.

We have now described the whole process of cotton spinning, and have only to explain how the thread is converted into cloth. The machine called a reel takes off the thread from the bobbins of the spinning frame and winds it into hanks, each of which is 840 yards in length, which are twisted up for package. The size of the thread is denominated by the number of these hanks which will weigh a pound; and in this state it is sent to market, where the weavers buy it. But various kinds of yarn are made for sale; some is dyed, others bleached; some twisted two threads together after spinning, and one of these threads is often dyed whilst the other remains white to produce speckled colours. Sometimes the thread is wound on quills for the weavers shuttle, at other times the yarn is formed into hanks previously to their being dyed, in order that the parts so tied may be prevented from taking the colour. This is done that the thread may be disposed to warp in the weaving loom, so as to produce the clouds which are seen in various species of cotton goods, especially gingams.

A large cotton mill is generally a vast building of five or six stories high; the two lowest are usually for the spinning frames, if they are for water twist, because of the great weight and vibration caused by these machines. The third and fourth floors contain the carding, drawing, and roving machines. The fifth story is appropriated to the reeling, doubling, twisting, and other operations performed on the finished thread. The sixth, which is usually in the roof, is for the batting machine or opening machine, and for the cotton pickers, who for a large mill are very numerous.

The general machinery of the cotton mill, by which the various engines described are set in motion, is as follows: the moving power, whether a fall of water or a steam engine, is, by intervening wheels adapted to its nature, made to turn round a vertical shaft, which passes through all the stories or floors of which the mill consists; in each of which it is furnished with a horizontal toothed wheel which gives motion to a vertical wheel, to which is attached a horizontal shaft going across one end of the floor, which gives motion to two or more other horizontal shafts, according to the breadth of the building, which run the whole length of the story. These again give motion to small vertical shafts which sustain the large drums that set the spinning frames in motion. The horizontal shafts have also drums on them, from whence bands proceed by which the carding engines and drawing machines are turned. What is said of the general arrangement of the millwork can only be understood in a general sense, for the number and position of the horizontal shafts set in motion by the vertical shaft must vary according to the nature of the buildings, and the disposition of the frames in each floor of them. Where it can be done, it is best to have the vertical shaft placed in the middle of the building, with the horizontal shafts proceeding from both sides of it at every floor, for then the horizontal shafts sustain less of that twisting motion which is very injurious to them, and to which they would be more liable if of the whole length of the building.

The spinning frames are attended by children to piece the threads when they break, and the whole attendance of the various engines is for the most part performed by children also. The numbers of persons of the tender age employed in large mills amount to several hundreds.

Some of the great cotton mills were worked incessantly night and day, and different sets of children relieved each other in succession in attending them. This system was found to be very injurious to their health. An act of parliament was passed enforcing salutary regulations on these points, which have been warmly seconded by the humane proprietors of some of the most eminent mills, who have their buildings now well ventilated and warmed. They have also paid proper attention to the food, clothing, and personal cleanliness of the children, and they have them taught to read and write, and take care that they receive instructions

structions as to their morals and religion both of which were shamefully neglected in former times.

We must now turn our attention to the weaving of the yarn, or twist so spun; the machine used in this process is the loom, there are a great variety of different looms, but the most simple and common is that used for weaving plain cloth of any materials, as cotton, thread, silk, wool, &c. &c. On examining any piece of plain cloth, it will be found to be composed of two distinct sets of threads or yarns, running in two directions perpendicular to each other, those threads in the direction of the length, are called the warp, and extend entire from one end of the piece of cloth to the other, those threads running across the cloth perpendicular to the warp, are called the woof or weft, it is in fact one continued thread through the whole piece of cloth, being woven alternately over and under each thread of the warp, until it arrives at the outside thread; it then passes round the thread and returns back over and under each thread as before, but in such a manner that it now goes over each thread which it passes under before, thus firmly knitting or weaving the whole together.

The outside thread of the warp round which the woof is doubled is called the salvage, and cannot be unravelled without breaking the woof.

The breadth of the cloth determines the number of threads the warp shall contain, and its quality or fineness limits the thickness of the threads and their distance asunder; these things being settled the weaver takes the proper number of threads of the right length and stretches them out parallel to each other in a field or long building, and rolls them all together upon a cylindrical roller A *Fig.* 1, called the yarn beam.

This at least was the practice formerly but the same operation is now performed much more conveniently and expeditiously by a machine called the warping mill; this is a very large reel on which the requisite number of threads are wound all together, and then transferred to the cloth beam.

After the cotton is spun it is frequently made into warps fit for the weavers before it leaves the mills. This operation is performed on the machine, called a warping mill, which consists of a light frame work forming the outline of an octagonal prism, or one of more numerous sides about six feet diameter, and seven feet high, that is turned round on a vertical axis by a band that passes from a grooved wheel on the axis, to another grooved wheel turned by a winch, and is placed under the seat on which the warper sits. The bobbins which sustain the twist, are placed on a vertical rack suspended from the ceiling and the threads from them pass between two small upright rollers, on a piece of wood which slides perpendicularly along an upright bar, fixed at one side of the revolving frame. A small cord passes from a part of the axis, that rises above the frame over a pulley at the top of the fixed bar down to the sliding guide, which it slowly draws up by coiling round the axis as the frame turns round, by which means the yarn is wound spirally about the frame, to the length of which the warp is required; to this extent when the yarn arrives it is crossed on pins projecting from the frame, and the mill is turned the reverse way, by which the slide descends, and the yarn is laid along the same spiral downwards along which it before ascended.

When the warp is completed to the number of threads required for the web, for which it is intended, it is taken off the mills and wound up into a ball, the crossing being first properly secured for the use of the weaver, and in this state it is sold to the weaving manufacturer when the mill owner is not concerned in this branch of business himself.

The weaver opens and unwinds this ball and rolls it up upon his cloth beam with very little trouble compared with the old method of extending all the yarns at once.

The beam thus filled with yarn, is placed in the Loom at B *Fig.* 14 *and* 15 *Plate* II, which are an end view and section of a loom, the other ends of the yarn are made fast to a similar beam A, called the cloth beam, and upon which they are rolled up after being made into cloth; *dd*, are two sticks connected together by several threads, the number of which is equal to half the number of yarns upon the warp, this system of threads is called a heddle, *ee* is another similar heddle. Behind the former, and in the middle of each thread, composing the heddle is a loop through which the yarns of the warp are passed, one half of them going through the loops of the heddle *ee*, and the other half passing between the threads of the heddle *ee*, and afterwards through the eyes of the other heddle *dd*. The two heddles *dd* and *ee* are connected together by two small cords going over pulleys *r*, suspended from the top of the loom, so that when one heddle is drawn down the other will be raised up, as shewn in the *figure* 14; the heddles receive their motion from levers or treadles DF moved by the weaver's feet, the yarns of the warp being passed alternately through the loops of the heddles, so that by pressing down one treadle as D, all the yarns *y* belonging to the heddle *d* are drawn down, and by means of the cords and pulleys *r*, the other heddle *e* with all the yarns *z* belonging to it are raised up, leaving a space of about two inches between the two sets of yarn.

FGGHI is a frame called the batten, suspended by its upper bar F from the upper rail of the loom, so that it can swing backwards or forwards. The bottom bar H shewn separate in *Fig.* 16, is much broader than the rails GG, and projects before their plane about an inch and a half, forming a sheff, called the shuttle race. The end of the bar H has boards nailed on each side of it, and at the ends to form two short troughs II, in which pieces of wood *kk*, called pickers or drivers are guided, by two small wires fixed at one end to the uprights GG, and at the other ends to the end pieces of the troughs II. Each pecker has a string fastened to it which is tied to a handle *p*, which the weaver holds in his right hand when at work, to pull the pecker backwards and forwards. The shuttle *Fig.* 17, is a small piece

piece of wood, pointed at each end, about six inches long, having an oblong mortice in it, containing a small bobbin K, on which is wound the thread for the woof, and the end of it comes through a small hole *m* in the shuttle called the eye.

The shuttle has two little wheels *n n*, on the under-side, by which it runs upon the shuttle race H. The weaver sits on the seat M, which hangs by pivots at its ends, that it may adapt itself to the most easy posture, when the weaver sits upon it; it is lifted out when the workman gets into the loom, and he puts it in after him; he leans his breast against the cloth roll A, and places his feet upon the treadles DE; in his right hand he holds the handle *p* of the peckers, and in his left he holds one of the uprights G of the batton; he commences the operation of weaving, by pressing down one of the treadles by his foot, this depresses one half of the yarns of the warp, and raises the others as before described, the shuttle is placed in one of the troughs I, against one of the peckers, then by drawing the handle of the pecker with a sudden jerk, drives the pecker against the shuttle, and throws it across the warp upon the shuttle race into the other trough I, leaving the thread of the weft which was wound on the bobbin K after it. With his left hand he then pulls the batten towards him by the frame of canes R, the thread of the warp before lying loose between the warp, is driven up towards the cloth roll, leaving it straight, the weaver now presses down his other foot, this reverses the operation, pulling down the heddle which was up before, and raising the other, the same of the yarn of the warp. By the other pecker, he now throws the shuttle back again, leaving the woof after it between the yarns of the warp, and by drawing up the batten, beats it close up to the thread thrown before; in this manner the operation is continued until a few inches of the cloth are woven; it is then wound round the cloth roll, by putting a short lever into a hole made in the roll, and turning it round. A click acting in the teeth of a serrated wheel *w*, *Fig.* 15, prevents the return of the roll; the yarn roll B has a cord lapped round it, one of the cords is tied to the frame of the loom, the other has a weight R hung to it; this rope causes a friction, which prevents the roll turning, unless the yarn is drawn by the cloth beam, this always preserves a proper tension in the yarn. TT are two smooth sticks put between the yarns, to keep their position and preserve the threads or yarns from entangling; these sticks or rods, are kept at a uniform distance from the heddles, either by tying them together, or by a small cord with a hook at one end, which lays hold of the front rod, and a weight at the other, which hangs over the yarn beam B. The cloth is kept extended during the operation of weaving, by means of two pieces of hard wood, with small sharp points in their ends, which lay hold of the edges or selvages of the cloth.

These pieces called the temples, are connected by a cord, passing obliquely through holes, or notches in each piece. By this cord they can be lengthened or shortened according to the breadth of the web. They are kept fast after the cloth is stretched, by a small bar, turning on a centre fixed in one of the pieces, with its longer end projecting closely over the edge of the other piece.

If the pattern, or course of changes, in the order of raising and depressing the threads of the warp be various, so that the weaver could not manage the requisite number of treadles, it is done by a great number of strings, which pass over pulleys above the loom, and are drawn one after another by a little boy, above whose head they are disposed in two rows by the sides, and between two looms. These looms are therefore called draw boys. The boys will shortly be set aside, for machinery which is rapidly introducing as a substitute. For the formation of sprigs, &c. of various colours, there are often as many shuttles as colours, or a number of little swivel looms, such as they use for the weaving of tapes, introduced occasionally, as many as there are sprigs in the breadth of a piece. Quiltings appear to be two distinct cloths, tied, as it were, together by stitches, which go through both cloths, and in some cases, as in bed quilts, there is a shuttle which throws in a quantity of coarsely spun cotton, to serve as a kind of wadding.

The counterpanes are woven with two shuttles, one containing a much coarser weft than the other; the coarser of the threads is picked up at intervals with an iron pin, rather hooked at the point, so as to form knobs disposed in a sort of pattern.

The webs, as the piece of cloth are called, when taken from the loom, are covered with an irregular knap or down, from the projection of the short fibres of the cotton wool, which is removed by passing the webs over a red hot iron plate that burns it off.

The apparatus for this operation, consists of an iron semi-cylinder, set horizontally in brick work, having a fire placed under it with an iron door, through which fuel may be introduced; at each side of this is placed a light wooden roller of rail work, turning freely on an iron axis by a winch; from the same uprights which support these rollers, are suspended light frames on each side, which turn on pivots in their centres, by depressing the further ends of which the ends next the stove raise up a rail, which runs across near the iron semi-cylinder, and which mostly consists of a light iron rod.

After the fire placed beneath the iron burner has made it red hot, the web, whose surface is to be burned is rolled up on one of these cylinders, or reels, and the end of it is passed over the lifters, and red hot iron to the other cylinder; a man stands at each reel, and the instant the one at the empty reel begins to turn, the lifters are lowered, so as to let the web come in contact with the red hot iron, by which means its whole surface is drawn over the iron, with that degree of velocity which is just sufficient to burn off those loose filaments without injuring its fabric. The very finest muslins undergo this operation, and though they are so thin

thin, that the least deviation from the proper velocity in passing them over the iron, causes them to be burned through, yet there very seldom happens any accident, which shews that the process is more hazardous in appearance than reality.

After burning, the webs are all washed in a wheel, and then bleached in the oxigenated muriatic acid, diluted to its proper strength. These preparations are repeated alternately, till the goods have attained the requisite whiteness; and between each dipping they are laid out upon the ground, and exposed to the action of the sun and air. When completely bleached, they are either smoothed upon long tables, with smoothing irons, or calendered, that is, stretched and pressed between a course of rollers, by which they acquire a fine gloss. Calicoes are printed exactly in the same way as the kerseymeres in Yorkshire, but the works are usually upon a much larger scale.

Thicksets, corduroys, velveteens, &c. are cut upon long tables, with a knife, of a construction somewhat like the sting of a wasp, terminating in a very sharp point, defended on each side by a sort of sheath.

This point is introduced under the upper course of threads, which are intended to be cut, and with great ease carried forward the whole length of the table.

The rapid increase of the cotton trade appears to have been owing in a great measure to the more liberal introduction of machinery into every part of it, than into any other of our staple manufactures. The utility and policy of employing machines to shorten labour, has been a subject which has exercised the pens of many ingenious writers, while their introduction into almost every branch of manufacture, has been attended in the outset with much riot and disorder. They are undoubtedly wonderful productions of human genius, the progressive exertions of which neither can, nor ought to be stopped; they enable a manufacture to produce a better article than can be made by the hand, in consequence of the uniformity, and certainty of their operations.

CURRYING.

Currying is the art of dressing or preparing leather for shoes, and a variety of other purposes, after it has undergone the process of tanning.

The currying trade has, like some others, been hitherto much neglected, in works of this nature, which may, perhaps, be attributed in a great measure to the difficulty of obtaining assistance from those who have it in their power to communicate the requisite information. Many valuable treatises have, no doubt, been furnished by men of practical knowledge in various branches of the arts and manufactures, but in general, principals in a manufacturing trade, however they may be inclined to disclose their secrets for the gratification of the public, are too much absorbed in their daily occupations to engage in undertakings foreign to their accustomed pursuits. This may be more particularly said of the currying trade, where personal attendance is indispensable, and it is scarcely necessary to add, that the persons usually employed in laborious occupations are not, in general, the description of men from whom an accurate and intelligent account of any art or manufacture can be reasonably expected. When, however, the manufacture of leather is compared with the other productions of this country, and its importance, as an article of commerce, and general consumption, is considered, it will appear desirable that the public, and those more immediately concerned, should be in possession of a circumstantial knowledge of the several branches of the leather trade. Our more general observations will be reserved as properly belonging to the article Tanning. We shall, at present, confine ourselves to that part of the trade which is comprehended in the article before us, introducing, by the way, such occasional remarks as are connected with the subject, in addition to the manual operations of the journeyman. Curriers exercise their trade under a license from the Board of Excise, which they take out annually, and they are obliged to specify in the entry, every room in which leather is deposited, as well as the vats and tubs in which it is soaked. Their premises are, of course, subject to the inspection of Excise Officers; and any hide or skin not having the tanners duty-mark, is liable to seizure. This is occasionally productive of trouble and vexation, as it frequently happens, that in rounding the skin, the duty-mark is cut off, unless the skin be stamped so far towards the middle and more useful parts, as to be an injury. By a late amendment of an Act of Parliament, the tanners in Scotland are said to enjoy the liberty of currying their own goods, but the implication is ambiguous, and in England the

union of the two trades is still prohibited under severe penalties. The only reason for this prohibition is probably to prevent the evasion of the tanners' duty, which might otherwise be facilitated, by transferring the tanned goods immediately into the hands of the currier; but if there should appear to be an advantage in uniting the trades of currying and tanning, of which under certain local circumstances we cannot entertain a doubt, this objection might be easily and readily obviated, by levying the Excise duty, not on the weight of the tanned leather, but on the measure of the tanners' pits, which has always been the practice in Ireland.

The premises of a currier usually consist of a shaving shop, scouring house, and rough leather warehouse, on the ground floor, and above these are erected the drying sheds, which are weather-boarded, and calculated to admit a free draught of air, where the wet leather is hung on hooks fixed in rails, which are placed horizontally in rows. The stuffing tables, which are of mahogany, are also fixed here; the lower floors are differently arranged by different persons, according to the extent of the premises, and the business to be carried on. Where a choice of situation offers, that will be preferred in which the air has free access to the sheds, and at a proper distance from foundries and steam engines, the smoke and smuts issuing from these buildings being a great annoyance to the currier, and injurious to saddle and boot-top leather in particular, the value of which depends much on the brightness and regularity of colour. An open yard is a useful appendage, and in extensive concerns cannot well be dispensed with. The coach and saddle currying is in many instances a distinct trade in London, but it is sometimes connected with the shoe trade, and in the country they are generally united and carried on by the same person.

The skin or shoe trade will come first under consideration, in which is comprehended the dressing of calf, seal, horse, and dog skins, with the lightest ox and cow hides, for shoe upper leathers; and to this is usually attached the business of a leather-cutter, which implies the cutting up of heavy tanned hides, called crop leather, for soles, and curried goods for shoe upper leathers, welts, &c. for the retailer and consumer. It is a general practice to weigh the skins and mark them singly before they are put into work, which enables the master to ascertain his profit on every lot of goods, or on every skin if he wishes to be so particular, and also assists his judgment in buying and assorting the different kinds of goods, and in applying them to the particular purposes for which they are calculated. This requires as much experience as any part of the trade, and a moderate profit is often wasted for want of proper attention in the person, usually the foreman in large concerns, who fills this department. In laying in rough goods the buyer should be well informed in the varieties of tannage, as well as the growth peculiar to different parts of the country, which are as readily distinguishable as the cattle themselves to an experienced dealer. Tanned goods are sold chiefly by weight, and the buyer must have in view the quality of the leather, pattern, and substance; the latter is unequal and varies in the same lot of goods and in different parts of the same skin. The proportion of thin loose leather to the middle or prime parts of the skin, is a principal consideration with the buyer, and he always finds the skin of the cow, or any other female animal more level, of a finer texture, and consequently more valuable than that of the male; the firmness and fineness of leather depends much on the treatment it has had in the tanner's pits. It is part of his duty to contract and fill the looser parts of the skin, which will be seen in its proper place; the gashing of the skin by the butcher, is also a matter of much consequence to the buyer and requires all his caution, as the extent of the mischief does not always appear, until the fibrous matter adhering to the flesh side, and which connects the skin to the carcase be removed by the currier's knife.

An act was passed in the year 1800, inflicting certain penalties on the butcher in proportion to the damage done to the skin, and persons have been appointed to the markets throughout the kingdom, to inspect the skins and levy the fines by information before a magistrate, in proportion to the damage, but it has been found inefficient from the total negligence of the inspectors in some places, and more so from the good understanding the Tanner finds it his interest to keep up with the butcher. Unfortunately the currier and not the tanner, who is the only check on the butcher, is the principal sufferer by his negligence. It may be matter of doubt how far enactments of this nature have a beneficial effect. We believe trade seldom does so well as when left to itself, at the same time it must be admitted that the law which we now speak of, if properly enforced, would go to prevent the destruction of much valuable property, and may be salutary so long as the tanning and currying trades remain separate.

The recent repeal of statute 1st, James I. has relieved the trade from a vexatious tax by abolishing the useless offices of Searchers and Sealers of Leather. Until the year 1808, Leadenhall Market was subject to the troublesome interference of these officers, who were obliged to compromise a duty it was impossible to execute; and we believe the most strenuous among those who at that time assisted in supporting such a regulation, now consider their own judgment well substituted for the obnoxious statute. The country leather dealers had long before wisely relieved themselves of its restrictions. Experience soon teaches the buyer to discriminate between well tanned and well dried leather, and the contrary, and according as a deficiency in either deteriorates the value so is the price given; this act also extended to currying and shoemaking, and persons annually appointed from among the master curriers paid a yearly visit to every house in the trade professedly to examine and correct any deviation from the established method of manufacturing their goods. They however very commendably satisfied themselves with exacting a small contribution from each house to defray the expenses

penses of a dinner for the collectors. To confine manufacturers to the use of certain materials and restrict curriers to the ancient mode of dressing leather would have been an effectual bar to improvement, and was too absurd to be acted upon at the present day; but to come to practical currying; the dressing of a calf skin for shoe upper-leathers will give a good general idea of the process; we will, therefore, take one as it is received from the tanner and pursue the operation through the hands of the workman to its finished state. The offal parts, such are the face, tail and shanks, being first taken off, which is called rounding the skin, it is delivered into the journeyman's hands, who throws it into a vat or tub of water to soak preparatory to the operation of shaving, which is performed by a knife of a peculiar make, and it will be necessary to give a description of this tool as well as the beam on which the leather is shaved. The beam, so called by the curriers, is a post about three feet high, fixed in a slightly inclined position on a firm stage or platform, which is raised eight or ten inches from the floor for the man to stand upon; this post is about four inches thick and eight inches wide, and is faced with a board of lignum vitæ of the same breadth. The knife has two edges, the blade is rectangular about twelve inches long and from four to six inches wide, and varying in size and weight according to the work to be performed; one end has a straight and the other a cross handle in the plane of the knife. It is brought to a wire edge by rubbing on a stone of a coarse grit, which is afterwards taken off, and a finer edge produced by a finer and softer stone. The cross handle of the knife is then firmly fixed between the workman's knees, and while in a kneeling posture, he turns the edges to an angle with their former position by means of a polished steel, similar in shape to a butcher's steel. They are kept in order, chiefly by a smaller steel, which the man holds constantly between his fingers, and passes along the knifes, the point within and the side without the groove formed by the turned edge, as occasion requires; and as often as the edges are worn with use they are renewed in the same way. The name of Cox of Gloucester, is known throughout Europe as the principal maker of curriers' knives. Lane of Cirencester is also an approved maker, and a patent has lately been obtained by Mr. Bingley of Birmingham, for an improvement in the manufacture of curriers' knives. These have not yet been sufficiently tried to decide on the merits of the improvement, but from what we have seen of them they are certainly well worth the master's attention. We say the master, because there is always a prejudice to encounter in the introduction of any new tool, or indeed any alteration whatever in the mode of manufacture. Having thus prepared the knife, the wet skin is thrown over the beam with the flesh side outwards, and the man keeps it in its position by the pressure of his knees as he leans over the beam. The knife is then applied horizontally to the leather, and by repeated strokes downwards it is reduced to the substance required. The angular edge does not merely scrape the skin, but in the hands of a skilful man takes off a shaving the full breadth of the beam at every stroke of the knife. The man's whole strength is exerted in shaving, and great care as well as ingenuity is necessary to avoid galling, or reducing the skin more in some parts than others. Long practice has not always been sufficient to make a man expert at this operation; many journeymen of long standing find a difficulty even in making the knife cut, and some have never attained the art. Here will be seen the importance of a well manufactured tool; a flaw or a crack in the metal renders it useless, and a regular temper throughout the knife is a desirable object, in which Mr. Bingley's are said to excel. He rivets a plate of steel properly tempered between two iron plates, instead of welding the whole together, which is the case with other makers; and thereby, as he properly observes, making the thicker and thinner parts unequal in temper according to the unequal influence of the same degree of heat on the thicker and thinner parts of the knife. In order to keep the substance of the skin equal, the man frequently examines it in the course of shaving in every part, by passing it double through his fingers, and when sufficiently reduced he throws it a second time into a tub of fresh water to be scoured and extended: for this purpose it is laid on a stone table, to which the flesh side adheres, and worked with the edge of a small square stone fixed in a stock or handle. Pumice stone is used, but not so much as formerly. With a brush the skin is cleansed from a whitish substance called the bloom, which all leather tanned with bark is found to contain. The natural folds of the grain disappear in the extension of the skin, and to effect this completely it is sometimes scoured a second time, for which the workman makes an extra charge. Changing the water has of itself a good effect in recovering *dead* or stale leather, and the trifling additional expense is well laid out. The skin is then removed to the drying shed, to be stuffed with a mixture of cod oil and tallow called dubbing, which is applied to both sides of the leather, but in larger quantities on the flesh than the grain side.

The dubbing is composed of about two parts oil and one part of tallow melted and well stirred together in cooling, so as to be perfectly incorporated in a smooth butter-like consistence. In conjunction with this mixture, sod oil, which is a mixture of the cod oil with the grease expressed from sheep skins, &c. by the skinners and feltmongers is sometimes used, but is never applied to bright coloured leather, and is much less used than in times past. Leather lightly stuffed will not wear so well as when it is rendered soft and flexible with the oil and tallow; and on the other hand, if over stuffed, the colour of the grain is darkened, and the oil itself, which moderately used is so great a preservative, becomes a cause of decay. The only motive for using more oil than adds to the quality of the leather is to increase the weight; but to admit of a good polish, less is usually applied than is really beneficial

ficial to the leather. The firmer and stronger parts of the skin require more than the looser parts to make them soft, which must be attended to in laying it on. In this state it is hung on the hooks to dry. In the course of drying most of the oily matter will be absorbed, and what remains on the surface still feeds the leather, and is suffered to continue until the skin is wanted for finishing. Severe frosty weather will of course suspend the scouring, drying, and stuffing, and is apt to injure the texture of the leather when frozen in the sheds, at the same time it brightens the colour; and the kinds of leather which are valuable on account of colour are consequently improved. The shed drying not being sufficient in winter, the leather is afterwards dried off in a stove, and then follows the boarding or bruising. The board used for this purpose is toothed or grooved, similar to the crimping board used by the ladies, and is slung on the hand by a leather strap. The skin is doubled and worked with a coarse board of this description until well softened, and is then *whitened* or lightly shaved over again with a half-worn pair of edges, which leaves the flesh side clean, and in a proper state to receive the colour used in waxing. Before it is waxed, however, it is boarded a second time, and the impression of the board often remains, particularly if the leather be not perfectly dry. The skin is now said to be finished russet, in which state it keeps best; and when wanted for sale it is again given out to be waxed. In London, this work is chiefly done by apprentices, being the most simple but the dirtiest part of the whole process. The blacking, usually termed colour, is a composition of oil, lamp-black and tallow, which is well rubbed into the flesh side with a hard brush, great care being taken to keep the grain side clean. A coat of strong size and tallow is then laid on with a soft brush, and is afterwards rubbed with a smoothing glass, and, lastly, it receives the finishing gloss from a little thin size laid on with a sponge. After the first coat of size the skin is hung up a few hours to allow the size and colour to dry and incorporate, and a lump of hard tallow is rubbed lightly over the surface. The skin is thus completely finished for the consumer, and leather so dressed is found superior in point of appearance and durability to any other method. Indeed, the blacking of the prime parts of calf leather on the grain has almost entirely given way to waxing; an additional reason for which may be that it is much better adapted for the polish it is afterwards to receive from the destructive shining blacking now in general use. The middle and firmer part of the skin only is fit for the better purposes, the outer and thinner portion being thrown by and sold at inferior prices. These offal parts are frequently cut off before the skin is put into work, and dressed separately from the butt or middle, and when that is the case it is usually blackened on the grain side. Horse, seal, and dog skins are also blackened on the grain, which varies the latter part of the process materially. After shaving, the leather is well washed with urine as a mordant on the scouring stone, to prepare it for the first application of a solution of copperas, which is given it in the course of scouring, and communicates the black dye. It is then stuffed in the manner before described, but more plentifully than waxed leather, and hung in the shed to dry; when taken down, the remains of the oily matter adhering to the surface of the leather is scraped off with a thin iron, formed and storked like the stone before mentioned, and which is afterwards made use of to stone or set the leather smooth on the table. Here it receives a second application of copperas and bullocks gall, which produces a complete black, and this part of the process is called seasoning. The copperas is applied with caution, lest by a too plentiful use of it the leather be injured. It should scarcely penetrate the cuticle or grain of the skin, and if used too strong the grain is burnt up and destroyed. The use of copperas is at all times injurious as may be daily observed in the use of black harness leather for instance, which cracks and decays sooner than brown leather. While the leather is damp with this liquid, and in the course of seasoning, the graining board is applied as before; only as the grain is now to be worn outwards, the workman is more particular in giving that side a neat appearance by raising the grain neatly and regularly. The coarser kinds of grain leather are also at this time hardened with a tooth slicker called a dicing iron, which leaves a lasting impression, or an artificial grain is imprinted by means of an engraved *roller* to imitate seal skin, which is found to answer better than the board covered with fish skin formerly in use. This is not done so much with a view to increase its value by imitating a better description of leather, as to harden and compress the looser parts of offal leather. It is now finished off with a little clear cod oil, and is termed grained offal. The thin parts of the horse hide are dressed in this manner, and are called *cordovan*, being probably an imitation of the manufacture of leather at Cordova in Spain. The Act of James, already referred to, prohibited the use of horse leather, clearly from ignorance in the legislators of that day, and the infant state of the manufactures of the country; horse leather having been found quite as useful as some other descriptions of leather, and little inferior to calf skin, and is now in very general use. The middle and stouter parts are cut out for boot legs; and as leg dressing is as curious (whether of calf or cordovan) as any part of the currying business, we shall be particular in describing the process. The piece intended for a leg being cut of a proper length, and tapering a little towards the small, is first soaked and scoured, having been already shaved in the hide, it is then marked and numbered to match its fellow, of a corresponding size and substance. The breadth of the small is measured, and the number of inches marked with a piece of copperas (which writes legibly on wet leather) as a guide for the bootmaker in fitting it to the leg. It is then blackened, if cordovan, but instead of again extending it on the scouring stone, it is worked inwards with the slicker, and the width partially reduced in that part which is

to form the small. The wet leather is then placed on a plain mahogany board between two curved irons approaching to a semicircle, the convex sides of which are made to approach and recede from each other, and are screwed down at a distance according to the size required for the small of the leg. The slicker is then employed to work the leather and contract it within the limits of the frame by which the breadth is reduced from two to four inches, and the leather thickened in proportion, or so much of the surface transferred to the substance; the leg thus treated will be elastic when dry, and after giving out sufficiently to admit the foot, closes to the shape of the wearer. This, however, is not so much a matter of attention since the introduction of Hessian boots, which are cut out of the finished skin, and stand hollow without regard to shape; but though the other description of legs called draft legs are not so much *taken in,* they continue to be dressed in the same way. The advantage of this method is nothing more than as it regards the fitting of a new pair of boots; frequent exposure to wet will soon destroy the effects of the currier's ingenuity. Leg dressing is the lightest and most profitable work to the journeyman in the shoe currying; it requires superior workmanship, and generally is given to the man most distinguished as a complete and able currier, or to the man who has been longest in the shop. The leg is stuffed, dried, and finished in the usual manner. Some few years since cordovan legs were exported in large quantities to North America, but from recent improvements in the art of currying in that part of the world, the demand has entirely failed; and cordovan having given way to calf legs for home consumption, the horse hide is now used chiefly for ladies' shoes. The Spanish American horse hides have lately been dressed thin and smooth on the grain to imitate kid leather, for which, as far as respects durability, it is a good substitute.

Perhaps it is not generally known that the *butt,* or that part of the horse hide which extends from the hip joints to the tail and is divided by the crupper, is much thicker than any other part of the skin, and the texture totally different. It consists of a callous substance called *shell* by the curriers, and has been used chiefly for thin soles and soldiers' stocks. It had always been considered difficult to shave from its brittleness constantly breaking away under the knife; but latterly, by using the precaution of stuffing it previously, it has been shaved and used for the backs of hessian boots, for which it is well adapted as it bears an admirable polish. The boar's skin has this peculiarity in a still greater degree as to substance, in that part which covers the breast and shoulders; it is called the boar's shield, from the means of defence it affords him. In the horse it is intended by nature for the same purpose, that animal being known when at liberty to receive the heels of his adversary on the part above mentioned. In the seal skin there is this remarkable property, that the skin is equally stout and firm in every part. Seal leather has a neat appearance, but being very soft and porous it admits wet, and is not so durable as most other kinds of leather, dog skins are tough, and good wear, and from their neatness are generally used for dress shoes; they are curried in the same manner as all other grain shoe leather; dressed leather cannot be kept long without injury, it always retains a degree of moisture, or if ever so well dried, imbibes it from the atmosphere, and consequently after laying together will become spotted with mildew; and if dressed with bad oil, it sticks together so firmly by means of a gummy substance, thrown out more or less by all stale leather, that the grain is often destroyed in tearing it asunder. When this is the case, the leather is in a perishing state, and of little comparative value; but wax leather is far less liable to this injury from keeping, than when blackened on the grain, the copperas adding to the effect, by its corroding properties. The fashionably white boot-top leather has been, and still is an object of competition; the finest calf skins are selected for this purpose, and it has exercised the ingenuity of most of the London curriers, to discover the means of extracting the colour of the tan, and to substitute a clear white, or cream colour, in its stead. An ingenious currier in the West of England, was in possession of a superior method of doing this, and reaped the benefit of his chemical knowledge exclusively for some years, and though the means he used have long since been no secret, in the method of applying them many are still deficient; and we believe few have equalled, and none have excelled his manufacture. Sumack is a principal ingredient in the composition, and that alone in the best tannages is effectual, but as suitable skins cannot be procured in sufficient quantities, it is found necessary to resort to a preparation of tin, which is also used in the bleaching of linen. Muriatic and vitriolic acid are applied to extract accidental stains, and are sometimes added to the boot-top composition, but have been found extremely pernicious to the leather. Immersion in a warm decoction of sumack, and the solution of tin, answers fully under proper management. The skirts and flaps and hog skins, for the seats of saddles, are now generally done in this way, and are brought to a perfection, in point of colour, never before known. The top-skin trade has, however, suffered materially since the introduction of *painted* boot-tops, which have an imposing appearance when new, and may be cleaned by simple washing with soap and water; but the great disadvantage is, that friction soon destroys the varnish, and totally precludes their use for riding. There are several other articles in shoe currying, such as *binding, welt leather,* &c. &c. which it would be trespassing too much on the reader's patience to describe minutely, and having already enlarged on the principal, we shall now pass on to the hide trade, which includes the dressing of ox and cow hides, for coach, harness, saddle, and military purposes; this, as was before observed, forms a distinct branch of the currying trade. Harness leather is dressed from the strongest and heaviest dressing hides, and the substance is not reduced in shaving, but merely the rough flesh

taken off; for reins, the butt is reduced to a level with the thinner parts, and for both these uses the hide is first divided, or slit down the back, from head to tail, for the convenience of the workman; and after being shaved and scoured, is blackened in the same manner as grain shoe leather. But before it is stuffed it is hung on the poles and semi-dried, and then stoned or set, in order to make the surface smooth, preparatory to receiving the dubbing, which is now laid on in quantities, proportioned to the substance of the hide, which is then replaced on the poles until nearly dry. The grain being cleansed with the urine and ox galls, it receives the last application of copperas. A roll of hard tallow is then rubbed over the grain, which the man works into the leather with a stone, and after a second coat of tallow it hangs up till completely dry; it now only remains to be finished with a smoother stone, or a glass of the same form. Brown harness differs only in the omission of the copperas and the tallow in finishing, and, perhaps, is not quite so much stuffed in the first place.

Japan hides, for the roofs and bodies of coaches, are shaved down to a thin substance, and carefully levelled, then stoned and set, and they are fit for the coachmaker's use; the japanning is the coachmaker's province after the hide is fitted to the coach body. Hides for the heads of open carriages are selected from light, roomy, and the least defective hides, and require the best of workmanship; they are blackened on the grain side, and the leather is softened, and the grain is raised in the same manner as black grain shoe leather. These hides, for the thinner purposes, being so very much reduced from their original substance, and the shavings of no other use than for fuel, an engine was invented, and has been many years in use, for splitting the hide into two parts, so as to divide the substance, and thereby obtain a useful piece of leather, which would otherwise be wasted in shavings, which it does in a very expeditious manner; the engine is in the hands of a person in London, who allows a small sum to the currier on each hide sent him to split, and reserves the flesh piece as his own remuneration. An ingenious attempt was made some years since to reduce the shavings to a pulp, and to reunite them so as to resemble pasteboard, by the same means as rags are converted into paper; we believe the intention was to use it for the covering of coaches, instead of the hide itself, but after repeated trials it was given up as a fruitless experiment.

The thinnest of all the hide leather is that which is used for the lining of carriages, it is dressed bright russet, but the coloured goat skins, called Morocco leather, are more generally applied. The seats of army saddles are cut out of thin hide leather, of this description, as being less expensive and quite as durable as hog skins, but the hunting saddles in general use are universally made of hog skins; the skirts and flaps are cut out to pattern, usually from the rough tanned hide, and go through the top skin process to improve the colour. Bridle leather is cut into pairs of *butts* and *middlings*, which signify the middle and butt of the hide; the neck and belly parts being used for inferior purposes. The army consumes vast quantities of leather for harness, saddles, caps, and accoutrements, which all go through the curriers' hands; and the Government Contracts for accoutrements &c. are great objects of contention in that line of business. The belts and straps are cut out of light cow hides, which are curried much after the manner the same kind of hides are done for strong shoe leather. Curried leather being strong in proportion to the substance, and more capable of resisting wet, is now preferred to losh or buff, for belts and straps, and the manufacture of buff is considerably diminished in consequence; it would be useless, and almost endless, to enumerate all the different purposes to which curried leather is applied; enough we trust has been said to make this branch of our manufactures intelligible, and we shall now advert to other matters connected with the trade; in the first place, the relations between master and man claim some attention. The frequent disagreements, and the inconveniences arising from them, have of late given importance to the subject, and as every person connected with the leather trade, (particularly curriers) are more or less interested in it, the few observations we shall make will not be deemed irrelevant.

The wages of a journeyman in the shoe or skin trade, are from thirty to forty-five shillings per week, according to his strength and ability, and in the hide trade it is not uncommon for a good workman to earn three pounds, this being heavier work. The men are paid by the job or piece, according to a printed list of prices agreed on between the masters and men in a committee, appointed by each of the parties, and the London list is a general guide for the country; this list is subject to occasional variations, but when a general advance is required by the men, it frequently if not always leads to disputes and sometimes to a general *turn out*, or refusal on the part of the men to work at the former prices. They usually take an opportunity of demanding an increase of wages, at a time when their employers have the greatest occasion for their services, and their demands are not always confined to the limits of equity. On the other hand the masters are sometimes backward in attending to their reasonable claims or in offering such an advance as may be proper in the circumstances of the case, until the pertinacity and independent spirit of the journeymen, compel them to take their demands into consideration from a regard to their own interest; the men have long since organized themselves into a friendly society, and raised a fund for the relief of their sick, and to support their travelling members while in search of work; this fund we believe is occasionally perverted, and enables them to contend with effect against their powerful opponents. Unanimity is however seldom to be depended on in either party, and their disagreements are generally brought to a crisis by secessions from both sides. Unreasonable as the men sometimes are we cannot applaud the conduct of the masters, when they resort to prosecutions for combinations,

tions, it is ungenerous to take an advantage which the law undoubtedly gives them of crushing and stifling the complaints of the men on whom they depend, and who are an acknowledged valuable and industrious part of the community. Every man has a natural and just right to set a price on the labour of his hands, " his labour (says an able and celebrated writer) is his property;" and a meeting of working mechanics, for the purpose of ascertaining and fixing its relative value is fully as justifiable in a moral view, as a meeting of merchants and tradesmen, to regulate and resolve on the prices they choose to compel the public to pay for their wares, which are the produce of labour, and is perhaps less a matter of real concern to the public or the legislature. It may be difficult to point out a distinction between the two cases of conspiracy, and we are in short of opinion that the market for labour as well as the produce of labour should be free, and doubt whether the policy which would go to deprive the working classes of this privilege, can be defended on any fair and equitable principle. From recent observation, and the consideration we have given to the subject, we are convinced that all the contentions between the men and their employers may be traced to the existing apprentice laws, which are the grand source of the evil. All those who have not served seven years are excluded thereby from getting their bread in the way and at the trade, that may be most congenial to their more mature inclinations, and also prevent the master from employing such persons, as may in his judgment best suit his purpose, and providing substitutes in case he should be deserted by his men. These laws consign young persons to a seven years' bondage indiscriminately, whether the particular trade to be learned may really require seven years or a seventh part of that time, and without regard to the age, abilities, or conduct of the lad; and this, as it should seem, for the purpose of giving the master the profits of his laborious industry. At the same time they place in the hands of the journeyman a monopoly, to which they have no just pretensions, to the invidious exclusion of a considerable portion of the industrious classes, from the more profitable application of their labour and talents. The laws against combinations and conspiracies are intended as a check, but are totally inadequate to counteract the result of so improvident an enactment, as recent circumstances have evinced, and it may be reasonably hoped, that the subject will not long escape the notice of the public.

Since writing the foregoing an additional duty has been laid on leather, of three halfpence per pound. On the policy of this tax we shall not now offer any remarks, having already trespassed on our limits, and shall only observe generally, that scarcely any town, however small, but has its currier, and leather curried in the country is mostly vended in the neighbourhood in small quantities to the consumers; but a sufficient proportion is sent for sale to London, to engage the attention of several respectable factors, and one house in particular makes the sale of dressed goods its chief concern. The currier derives his name from the word Coriarius, a worker in leather, and for the antiquity of the trade (although not the modern art of currying), the reader may be referred to the 17th book of the Iliad, line 450.

" As when a slaughter'd Bull's yet reeking hide
" Strain'd with full force and tugg'd from side to side,
" The *brawny Curriers* stretch, and labour o'er
" The extended surface, drunk with fat and gore,
" So tugging, &c.

The curriers have been an incorporated body ever since the reign of James I.

CUTLERY.

The manufacture of edged tools is one of the first arts among men in every state of society. Workmen in general are aware of the necessity that the instruments of their respective trades should be made to possess the qualities adapted to the operations by which they gain their subsistence: and, among the various subdivisions of labour, there is no material upon which the skill of mechanics is more exercised than steel. The makers of files, of chisels, of planes, and saws, and the infinite variety of knives, all occupy departments separate from each other, and possess their respective degrees of celebrity, which are grounded on their knowledge of the peculiar kinds of steel, as well as the methods of working them, which are best adapted to the intended operations. Many of these methods are kept secret; but there are some manufacturers who have no reserve with regard to the manipulations of their art, and have the spirit to assert their claims to public encouragement upon the fair ground of the address and integrity with which they conduct their labours. This article will be much indebted to the communications of Mr. Stodart, inserted in some of our periodical publications, and to a very able article on the subject in the New Cyclopædia.

Though cutlery, in the general sense, comprises all those articles denominated edge-tools, it is more particularly confined to the manufacture of knives, forks, scissars, pen-knives, razors, and swords. Damascus was anciently famed for its razors and swords. The latter are said to possess the advantages of flexibility, elasticity and hardness. Those articles of cutlery which do not require a fine polish, and are of low price, are made from *blistered* STEEL (which see). Those articles which require the edge to possess great tenacity, and at the same time superior hardness is not required, are made from sheer steel. The finer kinds of cutlery are made from steel which has been in a state of fusion, and which is termed cast-steel, no other kinds being susceptible of a fine polish. Table knives are mostly made of sheer-steel, the tang and shoulder being of iron, the blade being attached by giving them a welding heat. The knives after forging are hardened by heating them red hot, and plunging them into water; they are afterwards heated over the fire till they become blue and then ground. The handles of table-knives are made of ivory, horn, bone, stag-horn, and wood, into which the blades are cemented with resin and pulverized brick. Forks are made almost altogether, by the aid of the stamp and appropriate dies. The prongs only are hardened and tempered. Razors are made of cast-steel, the edge of a razor requiring the combined advantages of great hardness and tenacity. After the razor blade is forged, it is hardened by gradually heating it to a bright red heat and plunging it into cold water. It is tempered by heating it afterwards till a brightened part appears of a straw colour. It would be more equally effected by sand, or what is still better in hot oil, or fusible mixture, consisting of eight parts of bismuth, five of lead, and three of tin; a thermometer being placed in the liquid at the time the razors are immersed, for the purpose of indicating the proper temperature, which is about 500 of Fahrenheit. After the razor has been ground into its proper shape, it is finished by polishing. The glazor is formed of wood, faced with an alloy of lead and tin; after its face is turned to the proper form and size it is filled with notches which are filled up with emery and tallow. This instrument gives the razor a smooth and uniform surface and a fine edge. The polisher consists of a piece of circular wood running upon an axis, like that of the stone or the glazor. It is coated with leather, having its surface covered with crocus martis. The handles of high priced razors are made of ivory and tortoise shell, but in general they are of polished horn, which are preferred as well on account of their cheapness as their durability. The horn is cut into pieces and placed between two dies, having a recess of the shape of the handle. By this process the horn admits of a considerable extension; if the horn is not previously black, the handles are dyed black by means of logwood and green vitriol. The clear horn handles are sometimes stained so as to imitate the tortoise-shell: this is effected by laying upon the handle a composition of three parts of potash, one of minium, ten of quick-lime, and as much water as will make the whole into a pulpy mass. Those parts of the handle requiring darker shades, are covered thicker than the other. After this substance is laid upon the handles, they are placed before the fire the time requisite for giving the proper effect. The manufacture of pen-knives is divided into three departments; the first is the forging of the blades, the spring, and the iron scales; the second, the grinding and polishing of the blades; and the third, the handling, which consists in fitting up all the parts, and finishing the knife. The blades are made of the best cast steel, and hardened and tempered to about the same degree with that of razors. In grinding they are made a little more concave on one side than the other, in other respects they are treated in a similar

way

way to razors. The handles are covered with horn, ivory, and sometimes wood; but the most durable are those of stag-horn. The general fault in pen-knives is that of being too soft. The temper ought to be not higher than a straw colour, as it seldom happens that a pen-knife is so hard as to snap on the edge. The beauty and elegance of polished steel is not displayed to more advantage than in the manufacture of the finer kinds of scissars. The steel employed for the more valuable scissars should be cast steel of the choicest qualities; it must possess hardness and uniformity of texture for the sake of assuming a fine polish, great tenacity when hot for the purpose of forming the bow or ring of the scissar, which requires to be extended from a solid piece having a hole previously punched through it. It ought also to be very tenacious when cold, to allow that delicacy of form observed in those scissars termed ladies' scissars. After the scissars are forged as near to the same size as the eye of the workman can ascertain, they are paired. The bows and some other parts are filed to their intended form: the blades are also roughly ground, and the two sides properly adjusted to each other, after being bound together with wire and hardened up to the bows. They are afterwards heated till they become of a purple colour, which indicates their proper temper. Almost all the remaining part of the work is performed at the grinding mill, with the stone, the lap, the polisher, and the brush; the latter is used to polish those parts which have been filed, and which the lap and the polisher cannot touch. Previously to screwing the scissars together for the last time, they are rubbed over with the powder of quick lime, and afterwards wiped clean with a skin of soft sheep leather. The quick-lime absorbs the moisture from the surface, to which the rusting of steel is justly attributed. Scissars are sometimes beautifully ornamented by blueing and gilding, and also with studs of gold or polished steel. The very large scissars are partly of iron and partly of steel, the shanks and bows being of the former. These, as well as those all of steel, which are not hardened all over, cannot be polished: an inferior sort of lustre, however, is given to them by means of a burnish of hardened polished steel, which is very easily distinguished from the real polish by the irregularity of the surface. Having entered into these particulars relating to the manufacture of the usual articles found in cutlers' shops, we shall speak of some of the more general principles that are applicable to the finer articles of cutlery.

Cutlers do not use any coating to their work at the hardening heat as the file cutters do; and indeed it seems evidently unnecessary when the article is intended to be tempered and ground. The best rule is to harden as little as possible above the state intended to be produced by tempering. Work which has been overheated has a crumbly edge, and will not afford the wire hereafter to be described. The proper heat is a cherry red visible by day-light. No advantage is obtained from the use of salt in the water, or cooling that fluid, or from using mercury instead of water, but it may be remarked, that questions respecting the fluid are, properly speaking, applicable only to files, gravers, and such tools as are intended to be left at the extreme of hardness. Yet though Mr. Stodart does not seem to attach much value to peculiarities in the process of hardening, he mentions it as the observation and practice of one of his workmen, that the charcoal fire should be made up with shavings of leather: and upon being asked what good he supposed the leather could do, this workman replied, that he could take upon him to say, that he never had a razor crack in the hardening since he had used this method, though it was a very common accident before. It appears from the consideration of other facts, that this process is likely to prove advantageous. When brittle substances crack in cooling, it always happens from the outside contracting and becoming too small to contain the interior parts. But it is known, that hard steel occupies more space than when soft, and it may easily be inferred, that the nearer the steel approaches to the state of iron the less will be this increase of dimensions. If, then, we suppose a razor, or any other piece of steel, to be heated in an open fire with a current of air passing through it, the external part will, by the loss of carbon become less steely than before; and when the whole piece comes to be hardened, the inside will be too large for the external part, which will probably crack. But if the piece of steel be wrapped up in the cementing mixture, or if the fire itself contain animal coal, and is put together so as to operate in the manner of that mixture, the external part, instead of being degraded by this heat, will be more carbonated than the internal part, in consequence of which it will be so far from splitting or bursting during its cooling, that it will be acted upon in a contrary direction, tending to render it more dense and solid. One of the greatest difficulties in hardening steel works of any considerable extent, more especially such articles as are formed of thin plates, or have a variety of parts of different sizes, consists in the apparent impracticability of heating the thicker parts before the slighter are burned away; besides which, even for a piece of uniform figure, it is no easy matter to make up a fire which shall give a speedy heat and be nearly of the same intensity throughout. "This difficulty," says Mr. Nicholson, "formed a very considerable impediment to my success in a course of delicate steel work, in which I was engaged about seven years ago; but after various unsuccessful experiments, I succeeded in removing it by the use of a bath of melted lead, which for very justifiable reasons has been kept a secret till now. Pure lead, that is to say, lead containing little or no tin, is ignited to a moderate redness and then well stirred. Into this the piece is plunged for a few seconds; that is to say, until when brought near the surface that part does not appear less luminous than the rest. The piece is then speedily stirred about in the bath, suddenly drawn out and plunged into a large mass of water. In this manner a plate of steel may be hardened so as to

be perfectly brittle, and yet continue so sound as to ring like a bell; an effect which I never could produce in any other way. Mr. Stodart has lately made trial of this method, and considers it to be a great acquisition to the art, as in fact I found it." The letting down, or tempering of hard steel, is considered as absolutely necessary for the production of a fine and durable edge. It has been usual to do this by heating the hardened steel till its bright surface exhibits some known colour by oxidation. The first is a very faint straw colour, becoming deeper and deeper by increase of heat to a fine deep golden yellow, which changes irregularly to a purple, then to an uniform blue, succeeded by white and several successive faint repetitions of these series. It is well known, that the hardest state of tempered instruments, such as razors and surgeons' instruments, is indicated by this straw colour; that a deeper colour is required for leather-cutters' knives and other tools that require the edge to be turned on one side; that the blue which indicates a good temper for springs is almost too soft for any cutting instrument, except saws and such tools as are sharpened with a file, and that the lower states of hardness are not at all adapted to this use. But it is of considerable importance that the letting down or tempering, as well as the hardening, should be effected by heat equally applied, and that the temperatures, especially at the lower heats, where greater hardness is to be left, should be more precisely ascertained than can be done by the different shades of oxidation. Mr. Hartley first practised the method of immersing hard steel in heated oil, or the fusible compound of lead five parts, tin three, and bismuth eight. The temperature of either of these fluids may be ascertained in the usual manner, when it does not exceed the point at which mercury boils: and by this contrivance the same advantages are obtained in lowering the temperature of an whole instrument, or any number of them at once, as have already been stated in favour of my method of hardening. Oil is preferable to the fusible mixture for several reasons. It is cheaper; it admits of the work being seen during the immersion by reason of its transparency; and there is no occasion for any contrivance to prevent the work from floating.

Mr. Nicholson requested Mr. Stodart to favour him with an account of the temperatures at which the several colours make their appearance upon hardened steel; in compliance with which he made a series of experiments upon surgeons' needles hardened, highly polished, and exposed to a gradual heat while floating at the surface of the fusible mixture. The appearances are as follow: "No. 1. taken out at 430° of Fahrenheit. This temperature leaves the steel in the most excellent state for razors and scalpels. The tarnish, or faint yellowish tinge it produces is too evanescent to be observed without comparison with another piece of polished steel. Instruments in this state retain their edge much longer than those upon which the actual straw colour has been brought, as is the common practice. Mr. S. informs me (says Mr. Nicholson) that 430° is the lowest temperature for letting down, and that the lower degrees will not afford a firm edge. No. 2, at 440°, and 3 at 450°. These needles differ so little in their appearance from No. 1, that it is not easy to arrange them with certainty when misplaced. No. 4 has the evident tinge which workmen call pale straw colour. It was taken out at 460°, and has the usual temper of pen-knives, razors, and other fine edge tools. It is much softer than No. 1, as Mr. Stodart assures me, and this difference exhibits a valuable proof of the advantages of this method of tempering. Nos. 2, 6, 7 and 8, exhibit successive deeper shades of colour, having been respectively taken out at the temperatures 470°, 480°, 490°, and 500°. The last is of a bright brownish metallic yellow, very slightly inclining to purple. No. 9 obtained an uniform deep blue at the temperature of 580°. The intermediate shades produced on steel by heats between 500° and 580° are yellow, brown, red, and purple, which are exhibited irregularly on different parts of the surface. As I had before seen this irregularity, particularly on the surface of a razor of Wootz, and had found in my own experience, that the colours on different kinds of steel do not correspond with like degrees of temper, and probably of temperature in their production, I was desirous that some experiments might be made upon it by the same skilful artist. Four beautifully polished blades were therefore exposed to heat on the fusible metal. The first was taken up when it had acquired the fine yellow, or uniform deep straw colour. The second remained on the mixture till the part nearest the stem had become purplish, at which period a number of small round spots of a purplish colour appeared in the clear yellow of the blade. The third was left till the thicker parts of the blade were of a deep ruddy purple, but the concave face still continued yellow. This also acquired spots like the other, and a slight cloudiness. These three blades were of cast steel; the fourth, which was made out of a piece called styrian steel, was left upon the mixture till the red tinge had pervaded almost the whole of its concave face. Two or three spots appeared upon this blade, but the greater part of its surface was variegated with blue clouds, disposed in such a manner as to produce those waving lines which in Damascus steel are called the water. Two results are more immediately suggested by these facts; first, that the irregular production of a deep colour upon the surface of brightened steel, may serve to indicate the want of uniformity in its composition; and secondly, that the deep colour being observed to come on first at the thickest parts, Mr. Stodart was disposed to think, that its more speedy appearance was owing to those parts not having been hardened. Suppose our cutting instrument to be forged, hardened, and let down or tempered. It remains to be ground, polished, and set. The grinding of fine cutlery is performed upon a grind-stone of a fine close grit, called a Bilson grind-stone, and sold at the tool shops in London at a moderate price. The cutlers

cutlers use water, and do not seem to know any thing of the method by tallow. The face of the work is rendered finer by subsequent grinding upon mahogany cylinders, with emery of different fineness, or upon cylinders faced with hard pewter, called laps, which are preferable to those with a wooden face. The last polish is given upon a cylinder faced with buff leather, to which crocus, or the red oxide of iron is applied with water. This last operation is attended with considerable danger of heating the work, and almost instantly reducing its temper along the thin edge, which at the same time acquires the colours of oxidation. The setting now remains to be performed, which is a work of much delicacy and skill: so much so, indeed, that Mr. Stodart says, he cannot produce the most exquisite and perfect edge if interrupted by conversation, or even by noises in the street. The tool is first whetted upon a hone with oil, by rubbing it backwards and forwards. In all the processes of grinding or wearing down the edge, but more especially in the setting, the artist appears to prefer that stroke which leads the edge according to the action of cutting, instead of making the back run first along the stone. This proceeding is very judicious; for if there be any lump or particle of stone or other substance lying upon the face of the grinder, and the back of the tool be first run over it, it will proceed beneath the edge and lift it up, at the same time producing a notch. But on the other hand, if the edge be made to move foremost and meet such particle, it will slide beneath it and suffer no injury. Another condition in whetting is, that the hand should not bear heavy; because it is evident, that the same stone must produce a more uniform edge if the steel be wore away by many, than by few strokes. It is also of essential importance that the hone itself should be of a fine texture, or that its silicious particles should be very minute.

The grind-stone leaves a ragged edge, which it is the first effect of whetting to reduce so thin that it may be bended backwards and forwards. This flexible part is called the wire, and if the whetting were to be continued too long it would break off in pieces without regularity, leaving a finer though still very imperfect edge, and tending to produce accident while lying on the face of the stone. The wire is taken off by raising the face of the knife to an angle of about 50 degrees with the surface of the stone, and giving a light stroke edge foremost alternately towards each end of the stone. These strokes produce an edge, the faces of which are inclined to each other in an angle of about 100 degrees, and to which the wire is so slightly adherent that it may often be taken away entire, and is easily removed by lightly drawing the edge along the finger nail. The edge thus cleared, is generally very even: but it is too thick, and must again be reduced by whetting. A finer wire is by this means produced, which will require to be again taken off, if for want of judgment or delicacy of hand, the artist should have carried it too far. But we will suppose the obtuse edge to be very even, and the second wire to be scarcely perceptible. In this case the last edge will be very acute, but neither so even nor so strong as to be durably useful. The finish is given by two or more alternate light strokes with the edge slanting foremost, and the blade of the knife raised, so that its plane forms an angle of about 28 degrees with the face of the stone. This is the angle which by careful observation and measurement, I find Mr. Stodart habitually uses for the finest surgeons' instruments, and which he considers as the best for razors, and other keen cutting tools. The angle of edge is therefore about 56 degrees. The excellence and uniformity of a fine edge may be ascertained, by its mode of operation when lightly drawn along the surface of the skin, or leather, or any organized soft substance. Lancets are tried by suffering the point to drop gently through a piece of thin soft leather. If the edge be exquisite, it will not only pass with facility, but there will not be the least noise produced, any more than if it had dropped into water. This kind of edge cannot be produced, but by performing the last two or more strokes on the green hone. The operation of strapping is similar to that of grinding or whetting, and is performed by means of the angular particle of fine crocus, or other material bedded in the face of the strap. It requires, less skill than the operation of setting, and is very apt, from the elasticity of the strap, to enlarge the angle of the edge or round it too much."

We shall now, as a conclusion to the article, give an account of a patent granted to Mr. Arnold Wilde of Sheffield, for making all kinds of plane-irons, scythes, sickles, drawing-knives, and other edge-tools from a preparation of cast steel and iron united and incorporated by means of fire. This invention is thus described, "Take a mould of cast iron, or other fit material, of a dimension that will best suit the size of the article intended to be manufactured; then take a piece of wrought iron and prepare it by heating in the fire and hammering it, or in any other manner, to the size you want; then fix the iron in the mould, leaving a sufficient vacancy to receive the cast steel in a fluid state. In such a direction as that, when the cast steel is poured into the mould, the iron may be either in the middle or the centre of the cast steel, or on one or both sides of the cast steel, or in such other direction as may best suit the purpose for which the iron and cast steel when incorporated shall be wanted. Then put the crucible or pot into the furnace or fire till the steel becomes liquid. When you suppose the steel to be nearly in a fluid state, take your piece of iron which you intend to incorporate with the cast steel, put it into the fire and heat it to what is usually called a welding heat; then take the iron out of the fire, clear it from any scale of dirt, and fix it in the mould in the like direction you had before fitted it; take care that your steel be now in a fluid state, and immediately on your taking the iron out of the fire, take the crucible or pot containing the melted steel from the furnace or fire, and immediately after the iron thus heated shall be fitted in the

the mould pour or turn the fluid steel into the space or vacancy left in the mould to receive the same, which will incorporate with the iron, and become one solid mass or body of cast steel and iron united. To make all sorts of plane irons, scythes, sickles, drawing knives, hay knives, and all other kinds of edge tools of cast iron and steel, united as herein before mentioned, forge, roll, slit, or tilt in such a way as is proper for any or either of the articles intended to be manufactured; then the article may be made in the usual manner, or by such other mode as a workman may judge most convenient.

To harden Sword-blades.—Sword-blades are to be made tough, so as not to snap or break in pushing against any thing capable of resistance; they must also be of a keen edge, for which purpose they must all along the middle be hardened with oil and butter, to make them tough, and the edges with such things as shall be prescribed hereafter for hardening edged instruments. This work requires not a little care in the practice.

How to imitate the Damascan Blades.—This may be done to such perfection that they cannot be distinguished from the real Damascan blades. First polish your blade in the best manner, and finish it by rubbing with flour of chalk; then take chalk mixed with water, and rub it with your finger well together on your hand; with this touch the polished blade, and make spots at pleasure, and set them to dry before the sun, or a fire; then take water in which tartar has been dissolved, and wet your blade all over therewith, and those places that are left clear from chalk will change to a black colour; a little after, wash all off with clear water, and the places where the chalk has been will be bright.

How the Damascan Blades are hardened.—The Turks take fresh goat's blood, and after they have made their blades red hot, they quench them therein; this they repeat nine times running, which, it is said, makes their blades so hard as to cut iron.

DISTILLATION. See RECTIFICATION, in which article the processes of both operations will be given.

DYEING.

THE origin of the art of dyeing is involved in the same kind of obscurity which pervades the history of all those arts connected with the common wants and necessities of life. "They have," says a good writer, originated in times beyond the reach of history, or tradition, and are the offspring of the natural faculties of man directed by the great primeval wants of food, shelter and raiment. The art of dyeing is of course posterior to many of these, and is founded less on the necessities, than on the passions of mankind." A love of distinction is common to man in every stage of civilization, but that passion for admiration which is displayed in a love of ornament is peculiar to him in his most uncultivated state. Hence savage nations delight in brilliant and gaudy colours, and many paint their skins of various hues. Accident probably furnished a multitude of instances of observation which enabled the rudest people to imitate the colours of birds and beasts. The bruising of a fruit, a flower, or leaf, is one of the most natural and obvious occurrences to which we should look for the first notion of applying vegetable juices to dyeing, and the knowledge of tingent properties of various herbs was thus early acquired. Nevertheless the art must have waited the progress of industry and luxury before it became extended and improved. It probably made considerable progress, antecedent to the period in which regular history begins. Moses speaks of stuffs dyed blue, and purple, and scarlet, and of sheep-skins dyed red.

These colours, if they answered the names now made use of, in any tolerable degree, required much skill in the preparation, and the knowledge of them implies a very

very advanced state of the art at that period. We shall mention but a single fact, to shew in what way the knowledge of colours was first discovered. The colour which appears to have been earliest brought to perfection, and which was held in the highest estimation, was purple. It was to chance alone, according to the tradition of antiquity, that this was discovered. A dog, instigated by hunger, having broken a shell on the sea-shore, his mouth became stained with such a colour as excited the admiration of all who saw it. They applied it to stuffs, and succeeded. The testimony of Homer confirms the antiquity of this discovery; and this poet ascribes to the heroes of that age, in which it became known, ornaments and clothes of purple. The Tyrians succeeded best in dyeing stuffs of purple. They, it should seem, used nothing to make their colour but purple shells taken out of the sea. They made a bath of the liquor which they extracted from these fishes, in this they steeped their wool a certain time, and afterwards took it out, and steeped it in another boiler, in which was the buccina or trumpet fish. This is all that the ancients tell us of the practice of the Tyrians, and we learn that wool, which had received this double Tyrian dye, was so costly, that in the reign of Augustus, each pound sold for 1,000 Roman denarii, or about 36£. sterling. It is further added, that this excessive great price ought not to surprise us, when the tedious nature of the process is considered, and the small quantity of dye afforded by the shell-fish, from each of which not more than a single drop was obtained. For 50lbs. of wool they used no less than 200lbs. of the liquor of the buccinum, and 100lbs. of that of the purpura. The art of dyeing among the Greeks appears to have made no great progress; the dress of the people was of cloth that had received no dye, and which might be washed. The rich preferred coloured clothes: they esteemed such as were dyed scarlet with the kermes, but they valued still more highly those of purple. Among the Greeks, indeed, the useful arts were degraded, even in the estimation of philosophers, and this contempt descended to the Romans. The use of vegetable dyes appears to have been in a great measure unknown to these people, though the inhabitants of Gaul, according to Pliny, imitated all colours, even the Tyrian purple, and the scarlet, with the juice of herbs. According to this historian, they stained white cloths with certain drugs, which have the property of absorbing them, but which exhibited no appearance of any dye till they have been boiled in a cauldron, from which they are withdrawn painted or stained with various colours. What is most extraordinary, says Pliny, is, that the cauldron containing only colour of one hue, should impart to the cloth shades of various kinds, according to the nature of the drugs which were laid on, and the colours are so fixed that they can never be washed out.

These observations will give the reader some idea of the ancient methods of dyeing; it would not comport with the limits of our work to trace the history to the present period: much less to enter into the various theories advanced on the subject. The first explanation offered of the theory of dyeing was purely mechanical. According to Hellot, the saline substances employed in dyeing serve to open and enlarge the pores of the fibres to be dyed; the colouring matter is then deposited in these pores, after which the natural elasticity of the fibre returning, shuts in the particles of colouring matter, and the salts solidifying over them, serve as a kind of cement to keep them in their place. Many insuperable objections have been brought against this and similar theories of dyeing: it is particularly incompetent to explain the great difference between animal and vegetable matter in absorbing and retaining colour, and the use of mordants as a bond of union between the colour and the fibre to be dyed. Chemical affinity, which will be explained in its place, is probably the great agent in the operations of dyeing; almost every fact and experiment go to prove the truth of this opinion, which was first adopted by Bergman. A detailed account of all the processes, would fill a larger volume than that which we now offer to the public; all, therefore, that we can do, is to give a brief view of the leading facts and operations, and refer the reader to a few of the most satisfactory documents in our own and the French language, particularly to Bertholet's Elements of Dyeing.

Dyeing is the art of communicating a permanent colour to any substance, but is generally employed in a more limited sense, and is applied to the art of giving colours to wool, silk, cotton, or flax, or to thread of cloth fabricated of these substances.

The Colouring Principle is the property which substances possess of uniformly reflecting one or more rays of light from coloured bodies. These coloured bodies transferred to a white body, to which they impart their proper colour, form, in this way, colouring principles. Colouring bodies transferred to bodies already coloured, confound or mingle their colours with that of these same bodies, and hence is produced a mixt colour. The aptitude, or faculty of reflecting particular rays, is of little consequence. There are some bodies which display different colours according to the angle under which they are seen; while there are others, the mere pulverization of which changes the colour, without altering their nature.

Nothing more is necessary to enable us to form a judgment as to the facility with which the dispositions of bodies become changed in their property, of reflecting different colours, than to cast a cursory glance on the phenomena attendant on the oxydation of metals. Thus we behold successively appearing in them, blue, yellow, red, and black, from almost imperceptible differences in the proportion of the oxygen with the metal. The same phenomena are still more observable in vegetable and animal bodies, the colours of which appear or disappear according as the light acts upon them.

The colouring principle must not, therefore, be regarded as a particular colour, existing separately and distinctly from the coloured body. It is merely a faculty which the constituent parts of bodies possess, of reflecting

flecting particular rays of light decomposed at their surfaces. This faculty may be variously modified by changes produced in the arrangement of the molecules, by the proportions between the constituent principles, &c. We cannot foretel what may be the colour of a compound body, from the nature of the principles which compose it, when not previously ascertained by experiment. Frequently two colourless bodies form a coloured compound, as may be observed in metallic oxyds, of which the metal and oxygen are without colour. Hence it appears, that we can only ascertain, by a series of well-conducted experiments, what colours may be produced by the combinations of different bodies.

The colouring principles being as numerous as the coloured bodies, we may readily perceive how limited must be the conception of those chemists who see nothing but extracts or resins in colouring substances. The colouring principles are, every where, either simple or compound. They are regarded as simple, when the colour cannot be decomposed; such as blue, yellow, red, to which we may add the green and black furnished by vegetables. They are regarded as compound, when the colour results from the combination of several simple or primitive colours; such as violet, common green, &c.

It seldom happens that the simple colours, which by their combination form a compound colour, possess the same fixity, and are acted on in a similar manner by reagents; hence we are able to decompose a compound colour, and extract from it the elements separately. Hence may be explained, why a green colour becomes, in time, blue or yellow, according as these two principles possess more or less fixity. By changing the proportions of the elementary colours, a variety of different shades may be obtained, and in this way, by varying the mixture of green and blue, all the different shades from the lilac, to a very deep violet green, and nearly black, are produced. The colours of bodies often proceed merely from very slight modifications, produced by the action of light on their surfaces, as may be seen in the colours of fruits, flowers, and insects.

Sometimes the colour of bodies appears to be more deeply seated, as in substances, which are always of an uniform colour, when sheltered from the influence of air and light. Roots furnish us with examples of this kind. In general, the colour of bodies, when produced by the effects of light, is fugaceous, while that of substances protected from its influence is fixed and susceptible of forming good colours. It may be considered as an established principle that colour is so much more durable as the recipient resists more powerfully the influence of air, heat, and water. Hence it is, that resins, fecula, and metallic oxyds retain their colours better than mucous and extractive matters, &c. It must not however be inferred from this principle, that a good and permanent colour may not be obtained by employing certain mucous, or extractive matters; but then it is necessary to furnish it with a new base, so as to change the nature of the body, and consequently its affinities. Hence we are led to conclude, that the fixity of a colouring principle does not depend on its unalterability, but on the nature of the mordant with which it is combined, and on the affinities of this last combination with the stuff to which it is transferred; whilst the changeable nature of the colouring principle rests on the character of the recipient in which it is naturally held.

In regard to the nature of the coloured principles, the solvents ought to be greatly varied; water, acids, and alkalies are those most generally employed. Alcohol is seldom used, except when we wish to act on the colour of very small bodies. Of all these vehicles, water is the most common, because few of the colouring principles are insoluble in it.

Alkalies are employed to dissolve the colouring matter contained in indigo, in the flowers of bastard saffron, &c. The acids are used, in some cases, to dissolve certain colours, and particularly to precipitate the colouring principles from their solutions in alkalies.

Much has been written on the effects produced by waters in dyeing. And nothing is more common than to refer the brilliancy of some colours, and the poverty of others to this cause. Without adopting implicitly what has been published on this subject, it must be allowed that waters contribute essentially to the quality of dyes; and we may even add, that different colours, as well as the same colours in different states, require that waters of very different natures should be employed. To establish this second proposition, it is sufficient to take a cursory view of the principal operations of dyeing. If the object is to scour, or cleanse any stuff by soap, or alkali, the water must be pure; since otherwise the soap is decomposed by earthy salts, and there is formed a combination of oil and earth, insoluble in water, and incapable of producing the effect expected. The alkali likewise decomposes the earthy saline matter, becomes saturated with the acid, and produces no further effect, while the earth being set free, combines with the stuff, and changes its colour. Still and standing waters are, in general, the most saturated with earthy saline matters. Rapid and running waters are much more pure.

There are nevertheless some foul and almost stagnant waters which are greatly celebrated in dyeing, because the putrid animal and vegetable matters suspended in them operate to form ammonia and sulphureted hydrogen, which precipitate the earthy and metallic principles. Stagnant waters possess moreover the advantage over running waters in washing cotton stuffs, in order to free them from the alum or oil not fixed in their texture; for, in this case, it is necessary to moisten all the parts of the stuff, equally, to extract from it all the uncombined mordant; and it is difficult to accomplish this end by the employment of running water, without the colour being meagre, and blended with different shades. Clear and running water ought to be preferred for the cleansing of stuffs when taken out of the dyeing bath; they effectually remove every portion of matter not fixed in the stuff, and develope the colour in full perfection.

Waters

Waters impregnated with calcareous salts are particularly prejudicial to the dyeing cotton of a red colour. The lime which is precipitated by the galls, alum, and washing, tarnish and obscure the colour to such a degree that it is almost impossible to revive it. But in as far as calcareous earth tends to augment the solidity of the red colour and its modifications, selenitic waters do not prove injurious, where the object is to obtain a dark colour.

As calcareous salts change scarlet into crimson, it is obvious when this colour is the object, the use of selenitic waters must prove more advantageous than hurtful. Calcareous salts dissolved in water, exclusively of counteracting a change in colours, possess the inconvenience of weakening the solvent action of the liquid holding them in solution; whence it results, that the colouring principle is dissolved in a less quantity than in selenitic water. It appears to be an unquestionable fact, that the waters which keep the earths suspended, are less prejudicial than those which hold them in solution. In the first case they do not adhere to the stuff, while in the second they are precipitated by means of a double affinity, and enter into combination with a mordant which transfers and fixes them on the stuff. Of all the earthy principles which are found in water, lime is the most common, and that alone which can prove injurious. Alumine and magnesia never produce any bad effect.

The sulphate of iron is almost the only metallic salt found existing in waters; and in however small a proportion it be contained, it produces very sensible effects upon colours, particularly upon silk and cotton stuffs; those of wool are much less affected by it. The sulphate of iron acts, especially upon stuffs that have been subjected to the operation of galling, and produces brownish tints which modify all the colours imparted to them. The nature of the colouring principles not only regulates the choice of the solvents to be employed, but also enables us to assign to each its proper use. Thus coloured resins are dissolved in alcohol and form the colouring principle of varnishes.

Metallic oxyds when fused with alkalies, earths, &c. are employed to stain glass, enamels, and pottery-ware. Oils and fecula are dissolved in alkalies or lime; and the extractive principle is transferred to the stuff by the means of water. As we are yet very little acquainted with the cause of colour in bodies, we shall confine ourselves to relate some facts relative to the mode in which the colouring principle is developed.

In proportion as oxygen enters into combination with a metal, its colour becomes changed, and a difference in the proportions suffices to produce blue, yellow, red, black. The effect produced by the oxygen is more or less durable according to its affinities with the metal. Sometimes the colour disappears with the oxygen disengaged by a gentle heat; more frequently, however, the combination is so intimate, that it supports, without suffering any change, a heat approaching that of vitrification. Excepting some resinous bodies, and some extracts, the colours of vegetables are obtained by subjecting them to fermentation. Indigo, woad, turnsol, &c. furnish examples of this kind.

In all cases wherein a blue colour is produced by fermentation, it appears that carbon acts a chief part. Indigo contains twenty-three parts of carbon to forty-seven of colouring matter; vegetables yield by solution a carbon of a very fine blue; and it seems probable that when the blue colour is obtained by fermentation, the carbonaceous matter is nearly set free, and remains combined with an oil, which gives additional fixity to the colour, and indicates the most suitable solvent.

Of Mordants.—Few colouring principles possess such decided affinities as to form a permanent union with a stuff on contact or application alone. There are cases where the same vehicle which deposits the colour can also erase it; but this kind of daubing does not deserve the appellation of dyeing. Some metallic oxyds, especially those of iron, as well as several astringent and resinous substances, are susceptible of contracting a kind of adhesion to stuffs without any other intermedia. But in general the adhesion of the colouring principle with a stuff is facilitated by the intermedium of a third body which is termed a mordant.

Most chemists who have written on the subject of dyeing before chemical science had attained its present degree of perfection, have applied the most absurd theories to the action of mordants. Hellot, as we have seen, conceived, that the preparation given to stuffs in order to dispose them to receive the dye, acted by cleansing and opening the pores; and he adds, that it is probable the colouring particles are incased in these pores in the same manner as a diamond is set in the collet of a ring. Macquer has adopted the same theory; and we owe to Bergmann and Berthollet the improvement of conducting all the operations of dyeing on the general laws of affinities.

According to the principles adopted by these celebrated chemists, mordants must be regarded as the intermedia of the union or affinity between the colouring principle and the stuff. In combining separately the colouring principle with the mordant, or disposing this last on the stuff, we produce compounds endowed with affinities, in consequence of which they contract an union with bodies, which by themselves would have had no affinity with any of their constituent principles. The affinity of the mordant with the stuff, and with the colouring principle, may be rendered evident by direct experiments. M. Berthollet has shewn that wool boiled with alum decomposes a portion of this salt, and combines with the alumine; he has shewn further, that the undecomposed portion of the alum dissolved a little of the animal substance. The same chemist has demonstrated that cream of tartar and alum are not decomposed by boiling, though the cream of tartar is rendered more soluble by this mixture. He adds, that when a mixture of these two salts are boiled with wool, a decomposition takes place, which prove that the wool acts as an intermedium.

Wool

Wool boiled with alum alone is hard to the touch, but treated with cream of tartar and alum it feels soft, and receives a fuller and more vivid colour. The decomposition of alum by animal substances dissolved in alkali, proves that alumine combines with them. Thus, if a solution of alum be mingled with isinglass, and precipitated by an alkali, the alumine unites with the gelatine, forming a semi-transparent body which dries with difficulty. The decomposition of alum is not so readily produced by vegetable substances; though the astringent principle certainly decomposes it; and when this principle is deposited on a stuff, which after being dried is put into a solution of alum, a combination takes place between the alumine and tannin. In this case the concurrence of animal and vegetable substances produces a more perfect decomposition of the alum, as is evident in the preparation to which cotton cloth is subjected, in order to render it fit to receive a madder red.

To demonstrate the great affinity between alum and the colouring principles, it is sufficient to observe, that it forms the excipient of all the colours known in the arts under the name of lacs. When any coloured body is boiled in a solution of alum, and precipitated by an alkali, the alumine combines with the coloured precipitate and forms a lac. Alumine, according to the method of M. Thenard, may even be very intimately mixed with metallic colours, such as prussiate of iron, oxyd of cobalt, &c. In order that any body be fit to act as a mordant, it is not sufficient that it possess an affinity with the colouring principle, or with the stuff; it must also be perfectly white, otherwise its colour, mixing with that of the colouring principle, would produce a mixed colour. There are cases, however, in which certain bodies can serve at the same time as a mordant and a colouring principle; thus the oxyd of iron is employed along with a madder red, in order to dye cotton violet, and which, if employed alone, would produce a very deep nankeen colour.

Mordants ought to be little subjected to change by the action of the air and water; as otherwise they render the colours cloudy. We must not judge of a mordant, disposed on a stuff, and combined with the colouring principle from its original properties, as the new combination imports to it new qualities; and it is according to them that an opinion must be formed respecting it. Thus, for example, alumine which is very soluble in fixed alkalies, when uncombined with any other substance, becomes insoluble when, in the cotton prepared for Adrianople red, it is united with tannin and oil.

At present the two mordants most generally employed are, alum and muriate of tin. By decomposing alum by the acetate of lead, an acetate of alumine is obtained, which is preferable to alum, because the alumine is more easily disengaged from it, and the acid thus liberated is less corrosive.

The oxyd of tin possesses very marked affinities with the colouring principles, of which it heightens the colour, especially those of scarlet and madder red. The oxyd of iron displays more decided affinities with the stuffs, with which it combines in an almost indelible manner.

But as it is naturally coloured, it can only be employed in dyeing compound or mixed colours; in this last case the colour is harsh, unless it be softened by dipping such red stuffs in a solution of alum saturated with potash. The oxyd of copper is also employed as a mordant, but most generally in conjunction with iron in dyeing black; sometimes it is used alone in dyeing cotton of a yellow colour.

Lime, and all the calcareous salts may be considered as mordants; it is true they darken or obscure reds, but they give a brilliancy to the astringent principle, heighten blues, particularly metallic blues, and impart fixity to all colours.

The most complicated mordant employed in dyeing is that used for the Adrianople red; it is composed of alumine, oil, and the astringent principle. This combination of three bodies, which is successively formed by the numerous operations to which the cotton is subjected, possesses none of the properties of the three constituent bodies. And though the madder red may be fixed by any one of these three substances separately taken, yet the same degree of fixity is not imparted to it as when this triple combination is produced.

The best mordants are those which have not only a decided affinity with the colouring principle, but also with the stuff; and it is this property which renders alum preferable to all the other salts; but, as in general they have a greater affinity with the colouring principle than with the stuff, we first apply them to the stuff, and afterwards expose it thus prepared to the action of the colouring principle. If we pursue a contrary course, a lac will be formed, or the affinities between the alum and the colouring principle will be saturated, and exert no further action on the stuff. The mordant then applied to a stuff, first exerts its action on the stuff and combines with it; after which it attracts and retains the colouring principle.

The stuff can only imbibe a certain portion of alum, so that when it is completely saturated with this salt, it ought to be rinced through water, in order to free it from that portion of the alum which is not fixed; since, without this precaution, the superabundant alum will remain in the bath, and absorb the colouring principle, to the prejudice of the stuff. When the stuff is not washed after the process of aluming, it is boiled in the solution, or preserved wet for some time, in order to produce a more intimate union between it and the alum.

These processes are only proper for the preparation of woollen stuffs, which have more affinity with alum than those made of cotton or flax. The affinity of mordants with the stuff, is sometimes so great, that nothing more is necessary but placing it in their solution, in order fully to impregnate it with them.

Cotton

Cotton dipped in a solution of sulphate of iron, for example, almost instantaneously assumes a nankeen colour; and when the oxyd is suspended in the solution, it is sufficient to put the cotton into the bath for a short time, to fix it on the stuff, and to render the bath perfectly transparent. Although it is the general practice to impregnate the stuff with the mordant before the application of the colour, there is nevertheless exceptions to this rule; for example, in the manufactures of printed linens, when the object is to impress on the same stuff several different shades of blue, they first apply the colours with glue, and afterwards dip this species of painting successively into lime water, the solution of the sulphate of lime, and the lixivium of potash. When the colours are fixed by this means, the stuff is transferred into a bath, slightly acidulated by sulphuric acid, which purifies and whitens those portions of the stuff which have not been printed.

The mordant generally unites two properties, that of fixing the colour, and imparting to it brilliancy. If cotton, impregnated with the acetate of alumine, be dipped into a bath of quercitron, of a muddy dull colour, we see it immediately assume a brilliant yellow cloud, at the same time that the cotton becomes coloured.

When this composition is poured into a bath of cochineal, the colour instantaneously changes, and acquires the beautiful tint natural to scarlet. In this case, the oxyd of tin combines with the colour, and forms a compound, having such a strong affinity with the wool, that it is sufficient to plunge it into the bath, that it may extract all the colour. In the dyeing of some colours, it is necessary to employ separately one mordant for the stuff, and another for the colouring principle. For example, when we wish to impart a crimson colour to wool, the stuff is prepared with 5 oz. of alum to the pound of stuff; and the colouring bath is composed of 5 oz. of cochineal, and two ounces and a half of tartar; to this mixture is added, after it has reached the boiling point, ten ounces of the solution of tin.

Of the substances to which colours are communicated in the art of dyeing.—In the limited sense to which we have here restricted the art of dyeing, the substances to which colours are usually communicated by means of this art, are wool, silk, cotton, flax, and hemp. Of these, the two first are animal substances, and the three latter are derived from the vegetable kingdom. Animal substances are distinguished from those which have a vegetable origin, by the nature of their constituent parts. The former contain a large proportion of azote, which exists sparingly in the latter. Hydrogen is found in greater abundance in animal matters, than in vegetable productions. In the distillation of animal and vegetable substances, the difference of their constituent parts is not less remarkable. The former afford a large proportion of ammonia, the latter yield very little, and sometimes give out an acid. Animal matters afford much oil, while vegetable substances rarely afford it in any perceptible quantity. From the nature of their component parts, animal substances produce a bright flame in burning; and their combustion is accompanied with a penetrating odour, owing no doubt to the formation and emission of ammonia and oil. Animal matters run rapidly into the putrefactive process, while vegetable substances more slowly undergo the changes which are induced by fermentation.

The constituent principles of animal substances have a stronger tendency than those which enter into the composition of vegetable matters, to assume the elastic form, therefore the cohesive force existing between the particles of the former is inferior to that of the particles of the latter. Hence animal matters are more disposed to combine with other substances, more liable to be destroyed by different agents, and more readily enter into combination with colouring particles. Thus, animal substances are destroyed by the caustic fixed alkalies, and they are decomposed by the mineral acids. The action of acids and alkalies on silk is less powerful than upon wool, and it is less disposed to combine with the particles of colouring matter. In this respect it bears a resemblance to vegetable substances; but on these the action of alkalies and acids is less powerful than on animal substances; and the action of acids is more feeble on cotton than on flax or hemp.

We shall now treat of these substances: Wool, which is well known as the covering of sheep, derives its value from the length and fineness of its filaments. The filaments of wool are considerably elastic, for they may be drawn out beyond their usual length, and when the force is removed, they recover it again. They resemble the arrangement of the scales of a fish, which cover each other from the head of the animal to its tail. This peculiarity of structure of the filaments of hair and wool is proved by a simple experiment. If a hair be laid hold of by the root in one hand, and drawn between the fingers of the other hand, from the root to the point, scarcely any friction or resistance is perceived; but if it be grasped by the point, and passed in the same manner between the fingers from the point towards the root, a resistance is felt, and a tremulous motion is perceptible to the touch. Thus the texture of the surface of hair or wool is not the same from the root towards the point, as it is from the point towards the root. Wool is naturally covered with a kind of grease or oil, which is found to preserve it from insects or moths, and on this account the greasy matter is not removed, or the wool is not scoured till it is to be dyed or spun. The process for scouring wool is this: it is put for about a quarter of an hour into a kettle, with a sufficient quantity of water, to which a fourth part of putrid urine has been added. It is then heated, occasionally stirred, and being taken out, is allowed to drain. It is next put into a basket, and exposed to a stream of running water, and moved about till the grease is so completely separated, that it no longer renders the water turbid. The more carefully and completely this process is performed, the better the wool is fitted to receive the colouring matter. Our chemical readers will perceive the nature of the changes which are affected in this process of scouring.

scouring. The ammonia, which exists in the urine, combines with the oil of the wool, and forms a soap, which being soluble in water, is dissolved, and carried off. Wool is either dyed in the fleece, or after it is spun into threads, or when it is manufactured into cloth. For the purpose of forming cloths of mixed colours, it is dyed before it is spun; for the purposes of tapestry, it is dyed in the state of thread; but more frequently it is subjected to this process after it has been manufactured into cloth. In these different states, the quantity of colouring matter taken up is very different. The proportion is largest when it is dyed in the fleece, because then the filaments being more separated, a greater surface is exposed to the action of the colouring particles. For a similar reason the quantity of colour taken up is greater when in the state of thread or yarn, than when it is formed into cloth. But cloths themselves must vary in this respect, according to their different qualities. Their different degrees of fineness, or closeness of texture, will produce considerable variations; the difference also in the quantity and dimensions of the substances to be dyed, the different qualities of the ingredients employed and the different circumstances in which the process is performed, should be a caution against trusting to precise quantities, regulated by weight or measure, which are recommended according to general rules. According to the texture of the wool, and the nature of the colouring matter employed, it is found to be more or less penetrated with this matter. The wool from the thighs and tails of some sheep, receives colours with difficulty, and the finest cloth is never completely penetrated with the scarlet dye. The interior of the cloth appears always when cut, of a lighter shade, and sometimes even white.

Silk, which forms the basis of one of the richest and most splendid parts of dress, among the wealthy in civilized society, is the production of different insects. The phalæna bombyx, or silk worm, which is a native of China, attracted the attention of mankind in that country, from the earliest ages. The honour of having first collected and prepared silk from the cocoons in which it is wound up by the insect, during its metamorphoses, is ascribed to the wife of an emperor. The phalæna atlas, which is also a native of China, is said to form larger cocoons, and to yield a stronger silk. The silk-worm was first carried from China to Hindostan, and afterwards to Persia. About the middle of the sixth century, two monks returned from India to Constantinople, and brought with them a number of silk-worms, with instructions for managing and breeding them, as well as for collecting, preparing, and manufacturing the silk. Establishments were thus formed at Corinth, Athens, and other parts of Greece. The crusades, which though very injurious, in some respects to the world, greatly contributed to the diffusion of different kinds of knowledge, by the intercourse which took place between different countries, proved useful in disseminating the knowledge of rearing the silk-worm, and manufacturing its valuable productions. Roger, king of Sicily, about the year 1130, returning from one of these expeditions, brought with him from Greece, several prisoners, who were acquainted with the management of silk-worms, and the manufacturing of silk. Under their superintendence, manufactories were established at Palermo and Calabria. This example was soon adopted, and followed in different parts of Italy, and Spain. In the time of James I. an attempt was made to establish the silk-worm in England. For this purpose the culture of the mulberry-tree on which the insects feed, was recommended by that prince to his subjects; but the attempts have been hitherto unsuccessful.

The fibres of silk are covered with a coating or natural varnish of a gummy nature. To this are ascribed its stiffness and elasticity. Besides this varnish, the silk usually met with in Europe, is impregnated with a substance of a yellow colour, and for most of the purposes to which silk is applied, it is necessary that it should be deprived, both of the varnish and of the colouring matter. On this account it must be subjected to the operation of scouring. A hundred pounds of silk boiled in a solution of 20 lbs. of soap for three or four hours, adding new portions of water during the evaporation, are sufficiently prepared for receiving common colours. For blue, the proportion of soap must be increased; and scarlet, cherry-colour, &c. require still a greater proportion, for the ground must be whiter for these colours. Silk, which is to be employed white, must undergo three operations. In the first the hanks are immersed in a hot solution of 30 lbs. of soap to 100 of silk. When the immersed part is freed from its gum, which is known by its whiteness, the hanks are shaken over, so that the part which was not previously immersed may undergo the same operation. They are then wrung out and the process is completed. In the second operation the silk is put into bags of coarse cloth, each bag containing 20 or 30 lbs. These bags are boiled for an hour and a half, in a solution of soap prepared as before, but with less soap; and that they may not receive too much heat, by touching the bottom of the kettle, they must be kept constantly stirred during the operation. The object of the third operation is to communicate to the silk different shades, to render the white more agreeable. These are known by different names, as China-white, silver-white, &c. For this purpose a solution of soap is also prepared, of which the proper degree of strength is ascertained by its manner of frothing by agitation. For the China-white, which is required to have a tinge of red, a small quantity of anatto is added, and the silk is shaken over till it has acquired the shade which is wanted. In other whites, a blue tinge is given by adding a little blue to the solution of soap. The azure-white is communicated by means of indigo. It has long been an object of considerable importance, to deprive silk of it colouring matter, without destroying the gum, on which its stiffness and elasticity depend. A process for this

this purpose was discovered by Beaumé, but as it was not made public, others have been led to it by experiment. The following account, given by Berthollet, is all that has transpired concerning this process. A mixture is made with a small quantity of muriatic acid and alcohol. The muriatic acid should be in a state of purity, and should be entirely free from nitric acid, which would give the silk a yellow colour. In the mixture thus prepared, the silk is to be immersed. One of the most difficult parts of the process, is to produce a uniform whiteness. In dyeing the whitened silk, there is also considerable difficulty, to prevent its curling, so that it is recommended to keep it constantly stretched during the drying. The muriatic acid is useful in this process, by softening the gum, and assisting the alcohol to dissolve the colouring particles which are combined with it. The alcohol which has been impregnated with the colouring matter may be separated from it and purified, that it may serve for future operations, and thus render the process more economical. This may be done by distillation with a moderate heat, in glass or stone-ware vessels.

The preparation with alum is a very important preliminary operation in the dyeing of silk. Without this process, few colours would have either beauty or durability. Forty or fifty pounds of alum, dissolved in warm water are mixed in a vat, with as many pailfuls of water; and to prevent the crystallization of the salt, the solution must be carefully stirred during the mixture. The silk being previously washed and beetled, is immersed in this alum liquor, and at the end of eight or nine hours it is wrung out, and washed in a stream of water. A hundred and fifty pounds of silk may be prepared in the above quantity of liquor; but when it grows weak, which may be known by the taste, 20 or 25 lbs. of dissolved alum are to be added, and the addition repeated till the liquor acquires a disagreeable smell. It may even then be employed in the preparation of silk intended for darker colours, till its whole strength is dissipated. The preparation of silk with alum must be made in the cold; for if the liquor is employed hot the lustre is apt to be impaired.

Cotton is the down or wool contained in the pods of a shrubby plant, which is a native of warm climates. Of this genus of plants there are four species, one of which only is perennial, the other three are annual plants; but of these there are many varieties. The principal differences among cottons consist in the length and fineness of the filaments, and in their strength and colour. The peculiar structure of the fibres of cotton is not well known. According to the microscopic observations of Leuwenhoeck they have two sharp sides, to which are ascribed the irritation and inflammation of wounds and ulcers when they are dressed with cotton instead of lint. This peculiarity of structure may occasion some difference in the conformation and number of the pores, on which the disposition of cotton to admit and retain colours better than linen seems to depend. In this respect it is inferior to wool and silk, because on account of its vegetable nature, its affinity for colouring matter is less powerful. It is well known that silk, cotton, and linen have a weaker affinity for colouring matter than wool, which has been explained; that the pores of these substances are smaller than those of wool, and that the colouring particles enter them less freely. But according to Dr. Bancroft, the reverse of this seems to be the fact; for there is little difficulty in making silk, cotton, and linen imbibe colouring matter, even when it is applied cold without any artificial dilatation of the pores, which is always necessary in the dyeing of wool. The only difficulty is to make them retain the colours after the matter has been imbibed; because being admitted into their undulated pores, the particles cannot be afterwards compressed and retained by the contraction of these pores, as is the case with wool. It requires double the quantity of cochineal which is necessary for wool to communicate a crimson colour to silk; a proof that it can take up a greater quantity, and consequently that the pores are sufficiently large and accessible. Unbleached cotton is always preferred for dyeing Turkey red, because in this state the colour is found to be most permanent; which is ascribed to the pores or interstices being less open than after it has undergone the process of bleaching. The same thing is observed of raw silk. It is found to combine more easily with the colouring matter, and to receive a more permanent colour in this state than after it has been scoured and whitened. "The openness of cotton and linen, (says Dr. Bancroft) and their consequent readiness to imbibe both colouring particles, and the earthy or metallic bases employed to fix most of them, are circumstances upon which the art of dyeing and calico printing is in a great degree founded." To prepare cotton stuff for receiving the dye several operations are necessary. It must first undergo the process of scouring. By some it is boiled in alkaline lye: it should be kept boiling for two hours, then wrung out and rinsed in a stream of water till the water comes off clear. The stuffs to be prepared should be soaked in water mixed with not more than one-fiftieth part of sulphuric acid, and then carefully washed in a stream of water and dried. In this operation the acid combines with a portion of earth and iron, which would have interrupted the full effect of the colouring matter in the process of dyeing. Aluming is another preliminary process in the dyeing of cotton. The alum is to be dissolved, and each pound of cotton stuff requires four ounces of alum. By some a solution of soda, about one-sixteenth part of the alum, and by others a small quantity of tartar and arsenic are added. The thread is impregnated by working it in small quantities with this solution. The whole is then put into a vessel, and the remaining part of the liquor is poured upon it. It is now left for 24 hours, after which it is removed to a stream of water, and allowed to remain for an hour and a half or two hours, to extract part of the alum. It is then to be washed. By this operation cotton gains about one-fortieth part of its weight.

The

The operation of galling is another preparatory process in the dyeing of cotton stuffs. The quantity of astringent matter employed must be proportioned to its quality. Powdered galls are boiled for two hours in a proportion of water, regulated by the quantity of thread to be galled. This solution being reduced to such a temperature as the hand can bear, is divided into a number of equal parts, that the thread may be wrought in separate parcels. The whole stuff is then put into a vessel, and the remaining liquor poured upon it, as in the former process. It is then left for 24 hours, if it is to be dyed black, but for other colours 12 or 15 hours are found sufficient. It is then wrung out and dried. Berthollet informs us, that cotton which has been alumed acquired more weight in the galling than that which had not undergone the process; for although alum adheres but in small quantities to cotton, it communicates to it a greater power of combining, both with the astringent principle and with the colouring particles.

Flax and hemp nearly resemble each other in their general properties; and so far as relates to the processes of dyeing, what is said of the one may be applied to the other. Flax or lint is obtained from the back of linum usitatissimum, and hemp from that of cannabis sativa. Before flax is properly prepared to receive the dye, it must be subjected to several processes. The most important is that of watering, by which the fibrous parts of the plant are separated, and brought to that state in which they can be spun into threads. As the quantity and quality of the product depend much on this operation, it becomes of the greatest consequence that it be properly conducted. During this process, carbonic acid and hydrogen gas are given out. The extrication of these is owing to a glutinous juice which holds the green colouring part of the plant in solution, and which is the medium of union between the cortical and ligneous parts, undergoing a certain degree of putrefaction. This substance seems to resemble the glutinous parts which dissolved in the juice obtained from plants by pressure, is separated from the colouring particles by heat, readily become putrid, and by distillation affords ammonia. But although it is held in solution with the expressed juice, it cannot be separated from the cortical parts completely by means of water; and hence it happens, that hemp or flax watered in two strong a current, has not the requisite softness and flexibility. But if the water employed in this operation be stagnant and in a putrid state, the hemp or flax becomes of a brown colour, and loses its fineness. In the one case the putrefactive process is interrupted; in the other it is continued too long and carried too far. The process, therefore, is performed with the greatest advantage near the banks of rivers, where the water may be changed so frequently as to prevent such a degree of putrefaction as would be injurious to the flax, as well as prejudicial to the workmen from noxious exhalations; and yet not so frequently as to retard or interrupt those changes which are necessary for rendering the glutinous substance soluble in water. By watering flax, and by drying before and after that process, the green coloured particles undergo a similar change to that which is observed in the green substance of the plants exposed to the action of air and light. The next part of the process is to spread it out upon the grass, and thus expose it for some time to the air and sun. By this means the colour of the lint is improved, and the ligneous part becomes so brittle that it is easily separated from the fibrous part. This operation is usually performed by machinery. Flax which is intended for dyeing must be subjected to a similar series of operations with cotton in the different processes of scowering, aluming, and galling.

Of the operations of dyeing.—Before we proceed to the detail of the processes of dyeing, we shall throw out a few hints on the operations in general. The works, which are carried on in extensive manufactories, are followed with advantages which are unknown to those that are conducted on a limited scale or in a detached manner. By the subdivision of labour, each workman directing his attention to one or a few objects, acquires a great facility and perfection of execution, by which the saving of time and labour becomes considerable. This principle is particularly applicable to the art of dyeing, because the preparation which remains after one operation may be frequently employed in another. A bath from which the colouring matter has been in a great measure extracted in the first operation may be useful for other stuffs, or with the addition of a fresh portion of ingredients may form a new bath. The galls which have been applied to the galling of silk may answer a similar purpose for cotton or wool. A dyehouse, which should be set down as near as possible to a stream of water, should be spacious and well lighted. It should be floored with plaster; and proper means should be adopted to carry off water or spent baths by channels or gutters, so that every operation may be conducted with the utmost attention to cleanliness. The size and position of the chaldrons are to be regulated by the nature and extent of the operations for which they are designed. Excepting for scarlet and other delicate colours in which tin is used as a mordant, the caldrons should be of brass or copper. Brass, being less apt than copper to be acted on by means of chemical agents, and to communicate spots to the stuffs, is fitter for the purpose of a dyeing vessel. It is of the greatest consequence that the coppers or caldrons be well cleaned for every operation; and that vessels of a large size should be furnished at the bottom with a pipe and stop-cock for the greater convenience of emptying them. There must be a hole in the wall or chimney above each copper, to admit poles for the purpose of draining the stuffs which are immersed, so that the liquor may fall back into the vessel, and no part may be lost. Dyes for silk where a boiling heat is not necessary are prepared in troughs or backs, which are long copper or wooden vessels. The colours which are used for silk are

are extremely delicate. They must therefore be dried quickly, and not be long exposed to the action of the air, that there may be no risk of change. For this purpose, it is necessary to have a drying room heated with a stove. For pieces of stuffs, a winch or reel must be constructed, the ends of which are supported by two iron forks, which may be put up at pleasure in holes made in the curb on which the edges of the copper rest. The manipulations in dyeing are neither difficult nor complicated. Their object is to impregnate the stuff with the colouring particles, which are dissolved in the bath. For this purpose the action of the air is necessary, not only in fixing the colouring particles, but in rendering them more vivid; while those which have not been fixed in the stuff are to be carefully removed. In dyeing whole pieces of stuff, or a number of pieces at once, the winch or reel must be employed. One end of the stuff is first laid across it, and by turning it quickly round the whole passes over it. By turning it afterwards the contrary way, that part of the stuff which was first immersed will be the last in the second immersion, and thus the colouring matter will be communicated as equally as possible. In dyeing wool in the fleece, a kind of broad ladder with very close rounds, called by dyers a scraw or scray, is used. This is placed over the copper, and the wool is put upon it for the purpose of draining and exposure to the air. If wool is dyed in the state of thread, or in skeins, rods are to be passed through them, and the hanks turned upon the skein sticks in the liquor. To separate the superabundant colouring particles, or those which have not been fixed in the stuff, after being dyed, it must be wrung out. This operation is performed with a cylindrical piece of wood, one end of which is fixed in the wall, or in a post. This operation is repeated a number of times successively, for the purpose of drying the stuffs more rapidly, and communicating a brighter lustre. In dyeing, one colour is frequently communicated to stuffs with the intention of applying another upon it, and thus a compound colour is produced. The first of these operations is called giving a ground. When it is found necessary to pass stuffs several times through the same liquor, each particular operation is called a dip. A colour is said to be rosed, when a red colour having a yellow tinge is changed to a shade inclining to a crimson or ruby colour; and the conversion of a yellow red to a more complete red is called heightening the colour. We shall now make a few observations on the qualities and effects of different kinds of water, which may be considered as one of the most essential agents in the art of dyeing. It is almost unnecessary to say, that water which is muddy or contains putrid substances should not be employed; and indeed no kind of water which possesses qualities distinguished by the taste, ought to be used. Water which holds in solution earthy salts, has a very considerable action on colouring matters, which action is chiefly produced by means of these salts. Such, for instance, are the nitrates of lime and magnesia, muriate of lime and magnesia, sulphate of lime, and carbonate of lime and of magnesia. These salts, which have earthy bases, oppose the solution of the colouring particles, and by entering into combination with many of them, cause a precipitation, by which means the colour is at one time deeper and at other times duller and more faint than would otherwise be the case. Water impregnated with the carbonates of lime and magnesia, yield a precipitate when they are boiled, for the excess of carbonic acid which held them in solution is driven off by the heat; the earths are thus precipitated, and adhering to the stuffs to be dyed, render them dirty, and prevent the colouring matter from combining with them. It is of much consequence to be able to distinguish the different kinds of water which come under the denomination of hard water, that they may be avoided in the essential operations of dyeing; but to detect different principles contained in such waters, and to ascertain their quantity with precision, require great skill and very delicate management of chemical operations, which the experienced chemist only can be supposed to possess.

As it is not always in the power of the dyer to choose pure water, means of correcting the water which would be injurious to his processes, and particularly for the dyeing of delicate colours have been proposed. Water in which bran has been allowed to become sour, is most commonly employed for this purpose. This is known by the name of sours, or sour water. The method of preparing sour water is the following: twenty-four bushels of bran are put into a vessel that will contain about ten hogsheads. A large boiler is filled with water, and when it is just ready to boil it is poured into the vessel. Soon after, the acid fermentation commences, and in about twenty-four hours the liquor is fit to be applied to use. Water which is impregnated with earthy salts, after being treated in this way, forms no precipitate by boiling. It is probable that the sour water decomposes the carbonate of lime and magnesia, because the vegetable acid which is formed during the fermentation, combines with the earthy basis and sets the carbonic acid at liberty. Some of the substances with which waters are impregnated, or those which are merely diffused in them in a state of very minute division, may be separated by means of mucilaginous matters. The mucilage coagulates by means of heat, and carrying with it the earths separated by boiling as well as those substances which are simply mixed with the water and render it turbid, rises to the surface, and forming a scum may be easily removed.

Of the practice of Dyeing.—We have already endeavoured to give a general view of the principles on which the art of dyeing depends. We have considered the physical and chemical properties of colours and colouring matters; the nature of the substances to which colours are communicated, and the agents or means by which this is effected; and from the experiments and observations of philosophers, whose investigations have been directed to this subject, it appears that these changes

changes are entirely owing to chemical affinities, by which decompositions are effected, and new combinations formed among the constituent parts of the substances employed.

It is only by the application of the principles of chemistry that this art can be improved and perfected. But the application of these principles must be made by the practical dyer himself, not by the chemist in his laboratory, or during an occasional visit to the manufactory. For in the complicated processes of dyeing, conducted on an extensive scale, a thousand circumstances will be overlooked by the most acute and discerning chemist, which will not escape the habitual observation of the philosophical artist.

Colours have been usually distributed by dyers into two classes. These have been denominated simple and compound colours. Simple colours, which are commonly reckoned four in number, are such as cannot be produced by the mixing together different colours. Colours denominated compound may be produced by the mixture of any two of the simple colours in different proportions. Thus red, yellow, and blue, are incapable of being produced by any combination of others, and are therefore considered as simple colours. Blue and red, which compose a purple, blue and yellow a green, and red and yellow an orange, are compound colours; but none of these, by any composition whatever, will afford a red, yellow, or blue.

Dr. Bancroft, in his elaborate treatise on the philosophy of permanent colours, divides colouring matters into two classes. The first includes those colouring substances which, being in a state of solution may be permanently fixed on any stuff without any mordant, or the intermediate action of earthy or metallic bases. In the second class are comprehended those matters which cannot be fixed without the action of mordants. The first he has denominated substantive colours; because the colour is fixed without the aid of any other body: and the second adjective, because they become permanent only with the addition of a mordant. The celebrated purple produced by the liquor obtained from the shell-fish and indigo, are examples of substantive colours. Prussian blue and cochineal are adjective colours. The usual division of colours is into simple and compound, which seems to form an arrangement equally convenient and perspicuous.

OF SIMPLE COLOURS.

Simple colours are such as cannot be produced by the mixture of other colours. They are the foundation of all other colours, and therefore come naturally to be first treated of. The simple colours are four, viz. 1. Red. 2. Yellow. 3. Blue. 4. Black. To these a fifth is added by some; namely, brown, or fawn colour; although it may be produced by the combination of other colours. The nature of the colouring substances which are employed to produce these colours, and the processes by which they are fixed on the several stuffs, will form the subjects of the following article.

Red colours, from different degrees of intensity have received different names, as crimson, scarlet, besides a great variety of shades which are less striking, and come under no particular denomination. We shall treat of the nature and properties of the substances which are employed in dyeing red, yellow, blue and black, and then give an account of the different processes which are followed in fixing these colouring matters on animal and vegetable productions. 1. Of the substances employed in dying red. The colouring matters which are principally employed in dyeing red, are madder, cochineal, kermes, lac, archil, carthamus, brasil wood, and logwood.

Madder is very extensively employed in dyeing. It is the root of a plant (rubia tinctorum, Lin.) of which there are two varieties. It is cultivated in different parts of Europe, and the best, it is said, is brought from Zealand. Madder, as it is prepared for dyeing, is distinguished into different kinds. What is called grape madder is obtained from the principal roots; the *none* grape is produced from the stalks, which by being buried in the earth are converted into roots, and are called layers.

The roots being dried, and the earthy matters which adhere to them being separated by shaking them in a bag, or beating them lightly on a wooden hurdle, they are reduced to powder by means of manual labour or with machinery. All the parts of madder do not yield the same colouring matter. The outer bark and the ligneous part within give a yellowish dye, which injures the red. These parts may be separated in consequence of the different degrees of facility with which they are reduced to powder.

The result of the experiments of a French chemist shew, that the fresh root of madder may be used with as much advantage in dyeing, as when it is dried and powdered. Four pounds of fresh madder, he observed are equal to one of the dry, although in drying it loses seven-eights of its weight. When the fresh roots are to be used, they are to be well washed in a current of water immediately after they are taken out of the ground, and afterwards cut into pieces and bruised. In dyeing with the fresh roots, allowance should be made for the quantity of water which they contain, so that a smaller proportion should be put into the bath.

The colouring matter of madder is soluble in alcohol, and by evaporation a deep red residuum is formed. In this solution sulphuric acid produces a fawn-coloured precipitate; fixed alkali, one of a violet colour, and the sulphate of potash a precipitate of a fine red. Alum, nitre, chalk, acetate of lead, and muriate of tin, afford precipitates in the solution of madder in alcohol of various shades. The colouring matter of madder is also soluble in water. By maceration in several portions of cold water successively, the last receives only a fawn colour, which appears entirely different from the peculiar colouring particles of this substance. It resembles what is extracted from woods and

and other roots, and perhaps exists only in the ligneous and cortical parts. The colouring matter may be extracted either by hot or cold water; in the latter the colour is most beautiful. The decoction is of a brownish colour. The colouring matter of madder cannot be extracted without a great deal of water. Two ounces of madder require three quarts of water. Alum forms in the infusion of madder a deep brownish red precipitate; the supernatant liquor is yellowish, inclining to brown. Alkaline carbonates precipitate from this last liquor a lake of a blood-red colour; with the addition of more alkali, the precipitate is re-dissolved, and the liquor becomes red. Calcareous earth precipitates a darker and browner coloured lake than alkalies.

Cochineal, which furnishes a valuable dye stuff, and about the nature of which there was at first a good deal of uncertainty, is an insect. It is produced on different species of the cactus or Indian fig. When the Spaniards first arrived in Mexico, they saw the cochineal employed by the native inhabitants in communicating colours to some part of their habitations, their ornaments, and also in dyeing cotton. Struck with its beautiful colour, they transmitted accounts of it to the Spanish ministry, who about the year 1523, ordered Cortes to direct his attention to the propagation of this substance. The inhabitants of Europe were long mistaken concerning the nature and origin of cochineal, by supposing it to be the grain or seed of a plant. This opinion was first contradicted in a paper published in the third volume of the Philosophical Transactions, in 1668, and four years afterwards Dr. Lister, in the seventh volume of the same work, throws out a conjecture, that cochineal may be a sort of kermes. Different opinions concerning the origin of this substance were entertained till about the beginning of the year 1757, when Mr. Ellis obtained some of the joints of the plant on which the insects breed from South Carolina, and presented them the same year to the Royal Society. These specimens, Mr. Ellis observes, were full of the nests of this insect, in which it appeared in its various states, in the most minute when it walks about, to the state when it becomes fixed and wrapt up in a fine web which it spins about itself. With the assistance of the microscope, Mr. Ellis discovered the true male insect in the parcels which had been sent to him from America. It is supposed there may be 150 or 200 females for one male. These discoveries proved indisputably that the cochineal is an animal production. The female cochineal insect adheres to the same spot of the tree on which it is produced during her whole life. As soon as the female is delivered of its numerous progeny, it becomes a mere husk and dies. In Mexico it is therefore an object of great importance to prevent this, and to collect them in the fecundated state. For this purpose they are picked from the plants, put into a linen bag, which is immersed in hot water to destroy the life of the young insects, and then carefully dried. In this state they are imported into Europe.

Fine cochineal, if it has been properly prepared and kept, ought to be of a gray colour with a shade of purple. The gray colour is owing to a powder with which it is naturally covered, and part of which it still retains. The colouring matter extracted by the water in which the insect has been killed produces the purple shade. In a dry place, cochineal may be kept for a long time without losing any of its properties. Hellot made experiments on cochineal 130 years old, and found that it produced the same effect as if it had been quite new. Cochineal yields its colouring matter to water; and the decoction, which is of a crimson colour inclining to violet, may be kept for a long time without losing its transparency or becoming putrid. If this decoction be evaporated, and the residue or extract be digested in alcohol, the colouring part dissolves and leaves a residuum of the colour of wine lees, of which fresh alcohol cannot deprive it. The alcohol of cochineal affords, by evaporation, a transparent residuum of a deep red, which being dried has the appearance of a resin. A small quantity of sulphuric acid added to the decoction of cochineal, produces a red colour inclining to yellow, and a small quantity of a beautiful red precipitate.

The experiments of Berthollet and Bancroft shew that the colouring matter of cochineal is not entirely extracted by means of water. Dr. Bancroft found, that after the whole of it which could be extracted by water was obtained, by adding a little potash to the seemingly exhausted sediment, and pouring on it fresh boiling water it yielded a new quantity of colouring matter, equal to one-eighth of what had been given out to the water; and Berthollet found the same effect produced with the addition of tartar, from which he concludes that tartar favours the solution of the colouring part of the cochineal.

Kermes, another animal substance which is extensively employed in dyeing, is an insect that breeds on a species of oak which grows in most of the southern parts of Europe, and in many parts of Asia. Kermes is chiefly obtained from Languedoc, Spain, and Portugal. The insects are collected in the month of May or June, when the female, which alone is useful, is distended with eggs. To destroy the young insects, the kermes is exposed to the steam of vinegar for about half an hour, or steeped in vinegar for 10 or 12 hours. They are afterwards dried on linen cloths, and brought to market.

When the living insect is bruised it gives out a red colour. The smell is somewhat pleasant; the taste is bitter and pungent. It gives out its colouring matter both to water and alcohol, to which it also imparts smell and taste. The colour is also retained in the extract, which is obtained both from the tincture and from the infusion. Kermes is one of the most ancient dyeing drugs; and although the colours which it communicates to cloth are less bright and vivid than those of cochineal, and on that account it has been less extensively employed in dyeing since the latter was known, yet they have been found to be exceedingly permanent. The

The fine blood-red colour which is to be seen on old tapestries in different parts of Europe was produced from kermes, with an aluminous mordant, and seems to have suffered no change though some of them are 200 or 300 years old. The colour obtained from kermes was formerly called scarlet in grain, because it was supposed that the insect was a grain; and from the chief manufactory having been at one time in Venice, it was called Venetian scarlet.

Lac is an animal production which has been long known in India, and used for dyeing silk and other purposes. It is the nidus of the coccus lacca, and is generally produced on the small branches of the croton lacciferum. Three kinds of lac are well known in commerce: 1. Stick lac is the substance or comb in its natural state, forming a crust on the small branches or twigs. 2. Seed lac is said to be only the above separated from the twigs, and reduced into small fragments. Mr. Hatchett, who has examined this substance, found the best specimens considerably deprived of their colouring matter. According to the information which he received from Mr. Wilkins, the silk dyers in Bengal produce the seed lac by pounding crude lac into small fragments, and extracting part of the colouring matter by boiling. 3. Shell lac is prepared from the cells liquefied, strained, and formed into thin transparent lamina. The best lac is of a deep red colour; when it is pale and pierced at the top, the value is greatly diminished, for then the insects have left their cells, and it can no longer be of use as a dye stuff.

The decoction of powdered stick lac in water gives a deep crimson colour. With one-fifth of borax, lac becomes more soluble in water. Pure soda and carbonate of soda completely dissolve the different kinds of lac, and produce a deeper colour than that which is obtained by means of borax. Pure potash speedily dissolves all the varieties of lac; the colour approaches to purple. Pure ammonia and carbonate of ammonia readily act on the colouring matter of lac. Alcohol dissolves a considerable portion of the lac, and yields a fine red colour.

Archil is a vegetable substance of great use in dyeing. It is employed in the form of a paste, which is of a red violet colour. It is chiefly obtained from two species of lichen. The first, which is called Canary Archil, because the lichen from which it is prepared grows abundantly in the Canary islands, is most valued. It is prepared by reducing the plant to a fine powder, which is afterwards passed through a sieve and slightly moistened with stale urine. The mixture is daily stirred, each time adding a certain proportion of soda in powder, till it acquire a clove colour. It is then put into a wooden cask, and urine, lime-water, or a solution of sulphate of lime, (gypsum), is added in sufficient quantity to cover the mixture. In this state it is kept; but to preserve it any length of time, it is necessary to moisten it occasionally with urine. By a similar preparation, other species of lichen may be used in dyeing. In this country the "lichen omphalodes" and "tartareus" are frequently employed for dyeing coarse cloths. Archil gives out its colouring matter to water, ammonia, and alcohol. The infusion of archil is of a crimson colour, with a shade of violet. The addition of an acid converts it to a red colour. Fixed alkalies only render it of a deeper shade; because its natural colour has been already modified by the ammonia with which it is combined in the preparation. To cold marble the aqueous infusion of archil communicates a fine violet colour, or blue inclining to purple. The affinity between the stone and the colouring matter is so strong that it resists the action of the air longer than colours which it gives to other substances. The colour thus communicated to marble has remained for two years unchanged.

Archil is also soluble in alcohol. This tincture is employed for making spirit of wine thermometers. A singular phenomenon was observed by the Abbé Nollet when the tincture was excluded from the air. In a few years it was entirely deprived of its colour. The contact of air restored the colour; but it was again destroyed when deprived of it.

Carthamus, or bastard saffron, a vegetable substance used in dyeing, is the flower of an annual plant which is cultivated in Spain, Egypt, and the Levant. There are two varieties of this plant, the one with larger, the other with smaller leaves. The variety with larger leaves is cultivated in Egypt.

The method of preparing the flowers of carthamus in Egypt, as it is described by Hasselquist, is the following. After being pressed between two stones to squeeze out the juice, they are washed several times with salt water, pressed between the hands, and spread out on mats in the open air to dry.

Carthamus contains two colouring substances; a yellow substance which is soluble in water, and as it is of no use is extracted by the process mentioned above by squeezing the flowers between the stones till no more colour can be pressed out. The flowers become reddish in this operation, and lose nearly one half of their weight. The other colouring matter, which is red, is soluble in alkaline carbonates, and it is precipitated by means of an acid. A vegetable acid, as lemon juice, has been found to produce the finest colour. Next to this sulphuric acid produces the best effect, provided too great a quantity, which would alter and destroy the colour, be not employed.

From the colouring matter extracted by means of an alkali, and precipitated with an acid, is procured the substance called rouge, which is employed as a paint for the skin. The solution of carthamus is prepared with crystals of soda, and precipitated with lemon juice which has stood some days to settle.

Brazil wood is of very extensive use in dyeing. It is the wood of the cæsalpinia crista, Linn. and is a native of America and the West Indies.

The colouring matter of Brazil wood is soluble in water, and the whole of it may be extracted by continuing the boiling for a sufficient length of time. The decoction

decoction is of a fine red colour. The residuum, which is black, yields a considerable portion of colouring matter to alkalies. This colouring matter is also soluble in alcohol, and in ammonia, and the colour is deeper than that of the aqueous solution. The tincture of Brazil wood in alcohol gives to hot marble a red colour, which afterwards changes to violet. The fresh decoction yields, with sulphuric acid, a small portion of a red precipitate inclining to fawn colour. Nitric acid first produces a yellow colour, but by adding more, a deep orange. Oxalic acid produces a precipitate of an orange red. Tartar furnishes a small precipitate: with the addition of fixed alkali, the decoction becomes of a deep crimson or violet colour. Ammonia gives a brighter purple; alum produces a copious red precipitate, inclining to crimson. The decoction of Brazil wood, which is called juice of Brazil, is found to answer better for the processes of dyeing, when it has been kept some time, and has even undergone some degree of fermentation, than when it has been fresh prepared. The colour, by keeping, becomes of a yellowish red.

Logwood, sometimes called India or Campeachy wood, is a tree which grows to a considerable size in Jamaica, and the eastern shore of the bay of Campeachy. Its specific gravity is greater than that of water; it has a fine grain, and is susceptible of a fine polish. Logwood yields its colouring matter, which is a fine red, readily and copiously to alcohol. It is more sparingly soluble in water, and the decoction inclines a little to violet or purple. When it is left some time to itself, it becomes yellowish, and at length black. It becomes yellow also by the action of acids; alkalies produce a deeper colour, and convert it to a purple or violet.

Of Yellow.

In dyeing yellow, it is necessary to employ mordants, because the affinity of yellow colouring matters for either animal or vegetable stuffs, is not sufficiently strong to produce durable colours. Yellow colours, therefore, belong to that class which Dr. Bancroft has denominated adjective colours.

The substances capable of giving a yellow colour to different stuffs are very numerous; they do not all produce similar quantities of colouring matter; their dye is not equally free; the colours they impart incline more or less to orange or green; they possess various degrees of brightness and permanency, and differ considerably in price; circumstances by which the choice of the dyer ought always to be regulated. But those commonly employed in dyeing yellow, are *weld, fustic, anotta,* and *quercitron* bark.

Of the substances employed in dyeing yellow.—Weld is a plant which grows wild in Britain, and in different European countries. Its leaves are long, narrow, and of a bright green, but the whole plant is made use of in dyeing of yellow. There are two kinds of weld, cultivated and wild, the former of which is deemed more valuable than the latter, as it yields a much greater proportion of colouring matter. When this plant is fully ripe, it is pulled, dried, and bound up in bundles for the use of the dyer. The wild species grows higher and has a stronger stalk than that which is cultivated, by which the one may be readily distinguished from the other.

A strong decoction of weld is of a brownish yellow colour, and if very much diluted with water, the colour inclines to a green. An alkali gives to this decoction a deeper colour, and the precipitate it occasions is not soluble in alkalies. Most of the acids give it a paler tinge, occasioning a little precipitate which is soluble in alkalies. Alumina has so strong an affinity for the colouring matter of weld, that it can even abstract it from sulphuric acid, and the oxide of tin produces a similar effect.

Fustic is procured from a tree of considerable magnitude, which grows in the West Indies. The wood is yellow, as its name imports, with orange veins. Ever since the discovery of America it has been used in dyeing, as appears from a paper in the Transactions of the Royal Society, of which Sir William Petty was the author. Its price is moderate, the colour it imparts is permanent, and it readily combines with indigo, which properties give it a claim to attention as a valuable ingredient in dyeing. Before it can be employed as a dyestuff, it must be cut into chips and put in a bag, that it may not fix in and tear the stuff, to which it is to impart its colouring matter.

When a decoction of yellow wood or fustic is made very strong, the colour is of a reddish yellow, and when diluted it is of an orange yellow, which it readily yields to water. It becomes turbid by means of acids, its colour is of a pale yellow, and the greenish precipitate may be re-dissolved by alkalies. The sulphates of zinc, iron, and copper, as well as alum, throw down precipitates composed of the colouring matter and the different bases of the salts employed.

Anotta is a species of paste of a red colour, obtained from the berries of the *bixa orellana*, Linn., which is a native of America. The anotta of commerce is imported from America to Europe in cakes of two or three pounds weight, where it is prepared from the seeds of the tree mentioned above; but the Americans are said to be in possession of a species of anotta superior to that which they export, both for the brilliancy and permanency of the colour it imparts. They bruise the seeds with their hands moistened with oil, separating with a knife the paste as it is formed, and drying it in the sun; but the seeds are pounded with water when designed for sale, and allowed to undergo the process of fermentation.

Anotta yields its colouring matter more readily to alcohol than to water, on which account it is used in yellow varnishes, to which an orange tinge is intended to be given. Acids form a precipitate with a decoction of anotta of an orange colour, which is soluble in alkalies, but solutions of common salt produce no sensible change.

Quercitron, as it is denominated by Dr. Bancroft, is the

the *quercus nigra* of Linnæus, and is a large tree which grows spontaneously in North America. The bark of it yields a considerable quantity of colouring matter, which was first discovered by Dr. Bancroft in the year 1784, in whom the use and application of it in dyeing were exclusively vested for a certain term of years by virtue of an act of parliament.

Quercitron bark readily imparts its colouring matter to water at 100° of Fahrenheit, which is of a yellowish brown, capable of being darkened by alkalies, and brightened by acids.

Besides the substances already mentioned as employed in the dyeing of yellow, we may add saw-wort to the number, a plant which yields a colouring matter nearly similar to that of weld, and may of consequence be used as a proper substitute. Dyer's broom produces a yellow of a very indifferent nature, and is therefore only employed in dyeing stuffs of the coarsest kind. Turmeric is a native production both of the East and West Indies, and yields a more copious quantity of colouring matter than any other yellow dye-stuff; but it will probably never be of any essential service in dyeing yellow, as no mordant has yet been discovered, capable of giving permanency to its colour.

Chamomile yields a faint yellow colour, the hue of which is not unpleasant, but it is far from being durable, and even mordants are not capable of fixing it.

Fenugreek yields seeds which, when ground, communicate to stuffs a pale yellow of tolerable durability; and the best mordants are found to be alum and muriate of soda, or common salt.

In Switzerland and in England, the seeds of purple trefoil are sometimes employed in the art of dyeing, on which Vogler made a number of experiments, in order to ascertain what colours they would produce: and he found that a fine deep yellow was afforded by a bath made of a solution of these seeds with potash; that sulphuric acid yielded a light yellow, and sulphate of copper or blue vitriol, a yellow inclining to green. M. Dizé informs us, that the seeds of trefoil impart to wool a beautiful orange-colour, and to silk a greenish yellow; and that while aluming is necessary in the process of dyeing with the seeds of trefoil, a solution of tin cannot be employed.

Of Blue.

The next of the simple colours is blue. The only substances which are used in dyeing blue, are indigo and woad.

Indigo was not used for the purpose of dyeing in Europe, till near the middle of the 16th century. A substance is mentioned by Pliny, which was brought from India, and termed *indicum*, which seems to have been the same as the indigo of the moderns; but it does not appear that either the Greeks or the Romans knew how to dissolve indigo, or its use in dyeing, although it was applied as a paint. It was, however, known long before as a dye in India. The first indigo which was employed for the purpose of dyeing by Europeans, was brought by the Dutch from India. One of the species of the plant from which it is obtained, was discovered by the Portuguese in Brazil, where it grows spontaneously, as well as in other parts of America. Being afterwards successfully cultivated in Mexico, and some islands of the West Indies, the whole of the indigo employed in Europe was supplied from these countries. The indigo from the East Indies has, however, of late recovered its character, and is imported into Britain in considerable quantities.

There are three species of the indigo plant, which are usually cultivated in America. The first is the *indigofera tinctoria*, which besides being a smaller and less hardy plant, is inferior to the others on account of its pulp, but as it yields a greater proportion, it is generally preferred. The second is the *indigofera disperma*, or Guatimala indigo plant. This is a taller and hardier plant, and affords a pulp of a superior quality to the former. The third is the *indigofera argentea*, which is the hardiest of the three species, and yields a pulp of the finest quality, though in smallest proportion.

When the indigo plant has arrived at maturity, it is cut a few inches above the ground, disposed in strata in a large vessel or steeper, and being kept down with boards, is covered with water; and in this state it is left to ferment till the pulp is extracted. The process commences by the evolution of heat, and the emission of a great quantity of carbonic acid gas. When the fermentation has continued for a sufficient length of time, which is known by the tops becoming tender and pale, the liquor, which is now of a green colour, is drawn off into large flat vessels, called beaters, where it is agitated with buckets or other convenient apparatus, till blue flocculæ begin to appear. To promote this granulation or separation of the flocculæ, it is usual to add clear lime water till the liquor in which they are suspended becomes quite colourless. The liquor, being sufficiently impregnated with the lime water, is left at rest to allow the particles of the colouring matter to precipitate; after which the supernatant liquor is drawn off, and the sediment collected into linen bags, which are suspended for some time, to let the water drain off. It is then put into square boxes, or formed into lumps and dried in the shade. The indigo thus prepared is in a state fit for the market. Indigo exhibits various shades of colour, which is also owing to the mixture of foreign substances. The most common shades are blue, violet, and copper colour.

The object of the processes that are followed in the manufacture of indigo, is to extract from the plants which yield it, a green substance, which is soluble in water. This substance, which has a strong affinity for oxygen, gradually attracts it from the air, becomes of a blue colour, and is then insoluble in water. This absorption is greatly promoted by agitation, for then a greater surface is exposed to the action of the air; and the lime-water, by combining with carbonic acid, which exists in the green matter, also promotes the separation of the indigo.

Indigo

Indigo is employed in dyeing, both in the state of liquid blue, or as a sulphate of indigo, from which is obtained the beautiful colour called Saxon blue, and also in the state of simple indigo, or the indigo of commerce. In dyeing with indigo, it must be reduced to the state of the green matter as it exists in the plants, or when it is first extracted from them. It must be deprived of the oxygen, to the combination of which the blue colour is owing. In this state it becomes soluble in water by means of the alkalies. To effect this separation of the oxygen, the indigo must be mixed with a solution of some substance which has a stronger affinity for oxygen than the green matter of indigo. Such substances are green oxide of iron, and metallic sulphurets. Lime, green sulphate of iron, and indigo, are mixed together in water, and during this mixture the indigo is deprived of its blue colour, becomes green, and is dissolved, while the green oxide of iron is converted into the red oxide. In this process, part of the lime decomposes the sulphate of iron, and as the green oxide is set at liberty, it attracts oxygen from the indigo, and reduces it to the state of green matter, which is immediately dissolved by the action of the rest of the lime. Indigo is also deprived of its oxygen, and prepared for dyeing by another process. Some vegetable matter is added to the indigo mixed with water, with the view of exciting fermentation, and quick lime or an alkali is added to the solution, that the indigo, as it is converted into the green matter, may be dissolved.

Another plant, known under the name of pastel, or woad, is employed for dyeing blue, which is cultivated in France and in England. When the plant has reached maturity, it is cut down, washed in a river, and speedily dried in the sun. It is then ground in a mill, and reduced to a paste, which is formed into heaps, covered up to protect them from the rain, and at the end of a fortnight the heap is opened, to mix the whole well together. It is afterwards formed into round balls, which are exposed to the wind and sun, that the moisture may be evaporated. The balls are heaped upon one another, become gradually hot, and exhale the smell of ammonia. To promote the fermentation, which is stronger in proportion to the quantity heaped up, and the temperature of the season, the heap is to be sprinkled with water till it falls down in the state of coarse powder, in which state it appears in commerce. The blue colour obtained from woad is very permanent, but has little lustre.

Of Black.

The next of the simple colours is black. Of the substances employed in dyeing black.—There are few substances which have the property of producing a permanent black colour, without any addition. The juice of some plants produces this effect on cotton and linen. A black colour is obtained from the juice of the cashew nut, which will not wash out, and even resists the process of boiling with soap or alkalies. The cashew nut of India is employed for marking linen. That of the West Indies also yields a permanent dye, but the colour has a brownish shade. The juice of some other plants, as that of the toxicodendron, or sloes, affords a durable blueish black colour; but these substances cannot be obtained in sufficient quantity, even if they afforded colours equal to those produced by the common processes.

The principal substances which are employed to give a black colour are gall nuts, which contain the astringent principle, or tan, and the red oxide of iron. The black colour is produced by the combination of the astringent principle with the oxide of iron, held in solution by an acid, and fixed on the stuff. When the particles are precipitated from the mixture of tan and a solution of iron, they have only a blue colour; but after they are exposed for some time to the air, and moistened with water, the colour becomes deeper, although the blue shade is still perceptible. After the particles are fixed on the stuff, the shade becomes much deeper.

Logwood is not to be considered as affording a black dye, but it is much employed to give a lustre to black colours. We have already described its nature and properties, among the substances from which red colouring matters are obtained.

Black colours are rarely produced by a simple combination between the colouring matter and the stuff; but are usually fixed by means of mordants, as in the case of the black particles which are the result of a combination of the astringent principle and the oxide of iron, held in solution by an acid. But when the particles are precipitated from the mixture of an astringent and a solution of iron, they have only a blue colour. By being exposed to the air, and moistened with water, the colour becomes deeper, although the blue shade is still perceptible. No fine black colour is ever obtained, unless the stuffs are freely exposed to the air. In dyeing black, therefore, the operations must be conducted at different intervals. Berthollet has observed that black stuffs, when brought in contact with oxygen gas, diminish its volume, so that some portion of it is absorbed.

Of Brown.

The last of the simple colours is brown. This is also known under the name of fawn colour. It is that brown colour which has a shade of yellow, and might perhaps be considered as a compound colour, although it is communicated to stuffs by one process.

Of the substances employed in dyeing brown.—The vegetable substances which are capable of inducing a fawn or brown colour on different stuffs, are very numerous, but those chiefly employed for this purpose are walnut peels and sumach. The peels constitute the green covering of the nut; they are internally of a white colour, which is converted into brown or black by exposure to the air. The skin, when impregnated with the juice of walnut peels, becomes of a brown or almost black colour. When the inner part of the peel, taken fresh, is put into weak oxymuriatic acid, is assumes a brown colour. If the decoction of walnut peels be filtered

tered and exposed to the air, its colour becomes of a deep brown; the pellicles, on evaporation, are almost black; the liquor detached from these yields a brown extract completely soluble in water. The colouring particles are precipitated from a decoction of walnut peels, by means of alcohol, and they are soluble in water. No apparent change is at first produced by a solution of potash, but it gradually becomes turbid, and the colour is deepened. A copious precipitate of a fawn colour, approaching to an ash colour, is produced in a decoction of walnut peels, by means of a solution of tin, and the remaining liquor has a slightly yellow tinge.

A decoction of walnut peels yields a small quantity of fawn-coloured precipitate by means of a solution of alum, and the liquor remains of the same colour. The same properties are exhibited by a decoction of the walnut-tree wood, but the colouring matter is not obtained from it in such abundance as from the peels; and the bark may also be used with advantage in dyeing.

The affinity of the colouring matter of walnut peels for wool is very strong; and it readily imparts to it a durable colour, which even mordants do not seem capable of increasing, but they are generally understood to give it additional brightness. A lively and very rich colour is obtained with the assistance of alum. Walnut peels afford a great variety of pleasing shades, and as they require not the intervention of mordants, the softness of the wool is preserved, and the process of dyeing becomes both cheap and simple.

Walnut peels are not gathered till the nuts are completely ripe, when they are put into large casks, along with as much water as is sufficient to cover them. When used in dyeing at the Gobelins in Paris, Berthollet informs us, they are kept for upwards of a year, and very extensively used; but if not made use of till the end of two years, they yield a greater quantity of colouring matter, at which time their odour has become peculiarly disagreeable and fetid. The peels, separated from the nuts before they arrive at maturity, may likewise be used in dyeing, but in this state they do not keep so long.

Sumach is a shrub produced naturally in Palestine, Syria, Portugal, and Spain, being carefully cultivated in the two last of these countries. Its shoots are annually cut down, dried, and reduced to powder in a mill, by which process they are prepared for the purposes of dyeing.

The infusion of sumach, which is of a fawn colour with a greenish tinge, is changed into a brown by exposure to the air. A solution of potash has little action on the recent infusion of sumach; its colour is changed to yellow by the action of acids; the liquor becomes turbid by means of alum, a small quantity of precipitate being at the same time formed, and the supernatant liquor remaining yellow.

The bark of the birch-tree (*betula alba*, Linn.) yields a decoction of a clear fawn colour, but it soon becomes turbid and brown. The addition of a solution of alum in the open air, produces a copious yellow precipitate; a solution of tin gives also a copious precipitate of a clear yellow colour. With solutions of iron, the decoction of the birch-tree strikes a black colour, and it dissolves in considerable quantity the oxide of iron, but in smaller proportion than the decoction of walnut peels. On account of this property it is employed in the preparation of black vats for dyeing thread.

Saunders, or sandal wood, is also employed for the purpose of giving a fawn colour. There are three kinds of sandal wood, the white, the yellow, and the red. The last only, which is a compact heavy wood, brought from the Coromandel coast, is used in dyeing. By exposure to the air it becomes of a brown colour; when employed in dyeing, it is reduced to fine powder, and it yields a fawn colour with a brownish shade, inclining to red. But the colouring matter which it yields of itself is in small quantity, and it is said that it gives harshness to woollen stuffs. When it is mixed with other substances, as sumach, walnut peels, or galls, the quantity of colouring matter is increased; it gives a more durable colour, and produces considerable modifications in the colouring matter with which it is mixed. Sandal wood yields its colouring matter to brandy, or diluted alcohol, more readily than to water.

Having given some account of the general principles of dyeing, and of the substances made use of, we shall now confine ourselves chiefly to those facts that may be useful to private persons and families in the common concerns of life.

Two distinct manufactures belong to the subject of dyeing, the one is the art of giving an uniform colour to an entire piece of stuff; the other is the art of fixing various coloured patterns on an uniform ground, which being chiefly employed on cotton and calico, is called calico-printing. The fundamental principles of each art, as far as relates to the chemical action of the fibres of the stuff upon the different dyes and their mordants, is the same, but the particular modes of application widely differ. We shall now, as we have already observed, mention some of the more simple processes in the business of dyeing, after which we shall give an account of the art of calico-printing. The process of dyeing in the piece consists of a few simple operations, repeated two, three, or more times, according to circumstances, with many minute variations in the temperature, time of immersion, &c., according to the nature of the stuff, and the colour to be given, by rules, which, after all, experience and practice alone can teach. Our authorities will be the best that we can select from, viz. Berthollet, Bancroft, Hellot, Chaptal: the Encyclopedia Britannica; the British Encyclopedia, Aikin's Dictionary of Chemistry, and other works of established merit. It must, however, not be forgotten, that the variety in the processes actually used is almost endless: every dyer, whether on the small or large scale, having his particular receipt, in which slight variations in the quantity or quality of ingredients, the time or order of application, and other minute circumstances, are found to render the colour somewhat more or less full, durable, glossy, &c.

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The mode of dyeing Silk *or* Worsted *of a fine* Carnation *Colour.*—First take, to each pound of silk, four handfuls of wheaten bran; put it into two pails of water; boil it; pour it into a tub, and let it stand all night; then take half the quantity of that water, and put into it half a pound of alum, a quarter of a pound of red tartar, beaten to a fine powder, and half an ounce of finely powdered turmeric; boil them together, and stir them well about with a stick; after they have boiled for a quarter of an hour, take the kettle off the fire; put in the silk, and cover the kettle close, to prevent the steam from flying out: leave it thus for three hours; then rinse your silk in cold water, beat and wring it on a wooden pin, and hang it up to dry. Then take a quarter of a pound of powdered gall-nuts, and put the powder into a pail of river water; boil it for one hour; then take off the kettle, and when you can bear your hand in it, put in your silk, and let it lay an hour, then take it out, and hang it up to dry. When the silk is dry, and you would dye it of a crimson colour, weigh to each pound of silk, three quarters of an ounce of finely powdered cochineal; then put it in the pail with the remaining lye, and having well mixed it, pour it into a kettle; when it boils, cover it well, to prevent any dust falling into it. After you have put in three quarters of a pound of alum, and two ounces and a half of tartar, both finely powdered, let it boil for a quarter of an hour; then take it off the fire; let it cool a little, and put in the silk; stir it well with a stick, to prevent its being clouded; and when cool, wring it out. If the colour is not deep enough, hang the kettle again over the fire; and when it has boiled, and is grown lukewarm again, repeat the stirring in of the silk; then hang it upon a wooden pin fastened in a post, and wring and beat it with a stick; after this, rinse the dyed silk in hot lye, wherein, to one pound of silk, dissolve half an ounce of Newcastle soap; afterwards rinse it in cold water. Hang the skeins of silk on a wooden pin, putting a little handstick to the bottom part, and thus having worked it, wring it and beat it round, and hang it to dry.

Another method of dyeing Silk a Crimson *Red.*—Take of good Roman alum, powdered, half an ounce; tartar, powdered, one ounce; sulphuric acid a quarter of an ounce; put them into a pewter kettle, and pour as much water on them as is sufficient for half an ounce of the silk you purpose dyeing; when it is ready to boil, put in the silk, which before you must boil in bran; boil it for an hour, or more; then wring it out, and put to the liquor half an ounce of cochineal, finely powdered, and sixty drops of sulphuric acid; when ready to boil, put in the silk again, and let it soak for four hours; then take clean water, drop into it a little of this acid; rinse therein the silk; take it out again, and dry it on sticks in the shade. This will be a high colour: but if you would have it of a deep crimson, take, instead of sulphuric acid, pure water of ammonia, to rinse your silk in.

General Observations in dyeing Crimson, Scarlet, or Purple.—1st. Your boiler or kettle must be of good pewter, quite clean, and free from any soil or grease. 2d. The prepared tartar must be put in when the water is lukewarm. 3d. If you intend to dye woollen or worsted yarn, you may put it in the first boiling, and let it boil for two hours. 4th. When boiled, take it out, rinse it, clean the kettle, and put in the water for the second boiling. 5th. This second boiling is performed in the same manner as the first; then put in cochineal, finely powdered; when it boils, stir it well about. 6th. Now the silk, which before has been washed and cleansed in the first lye, is to be put in, on a winch, which is continually turned about, in order to prevent the colours from fixing in clouds. 7th. When the colour is to your mind, take it out; rinse it clean, and hang it up in a room, or a shady place, where it may be free from dust. 8th. When the acid is put into the second boiling, it causes a coarse froth to swim at top, which you must carefully take off.

Of Scarlet Dyeing.

Scarlet dyeing, in general, is a distinct and separate branch of trade, the materials being of that delicate kind as easily to be injured by any accidental admixture of other colours, and part of the apparatus being somewhat different from common dyeing. The boiler, in which the cochineal bath is made, is generally of tin or strongly tinned copper; because a solution of tin is the mordant employed in the process, and therefore no mischief can arise from its being in contact with the same metal. The water made use of must be soft and pure, hard water having a tendency to produce a rose-colour, which, however, is corrected by boiling bran or starch in it. The infusion of cochineal is naturally of a fine crimson, and with a mordant it fixes on woollen and silk with great firmness, but weakly and with considerable difficulty on linen and cotton. Alum was the first employed to fix the colour of cochineal on wool. It does sensibly alter the natural tint, and it gives a deep and durable crimson. It will even restore the crimson to cloth dyed scarlet by the compound *tin* mordant. The effect of tin in heightening the colour of cochineal was discovered by a German chemist, named Kuster, who was settled at Bow in the vicinity of London, about the year 1543, and on this account scarlet is called the Bow-dye in this country.

Woollen cloth is usually dyed scarlet in two operations, though a single one will suffice, but in general it is less convenient.

To dye 100lbs. of wool or woollen cloth Scarlet.—Take 8 or 10 pounds of tartar, put them into the boiler with a sufficient quantity of soft water, and six or eight ounces of cochineal. Afterwards 10 or 12 pounds of the nitro-muriate of tin are to be added, and when the mixture is ready to boil, the cloth, previously wetted, is put into the dyeing liquor, turned through it by a winch for an hour and a half, the liquor being kept boiling the whole time. The cloth is then taken out and rinsed, and is found by this first process to have acquired

quired a flesh colour. The boiler is now emptied, and again filled with fresh water, and when nearly boiling, from five to six pounds of cochineal are thrown in, and well stirred; after which ten pounds more of the solution of tin are added, and the cloth is then put in, and turned through the boiling liquor, at first briskly, and then slowly for half an hour. It is then washed and dried in the usual manner. The proportion of cochineal to dye a full scarlet, is an ounce to a pound of cloth; hence, from the high price of this article, the cochineal dye is one of the most expensive of all the processes in the whole art of dyeing.

When a bright flame-coloured scarlet is wanted, a little yellow fustic is added to the first bath, or else some turmeric is added to the cochineal in the second.

The ease with which alkaline and earthy salts counteract the yellow part of these colours, causes the scarlet cloth to be changed more or less to a rose or crimson by *fulling*. If the scarlet, when finished, has too much of an orange tint, this may be corrected by afterwards boiling the cloth in a hard water, or one that contains an earthy salt. After the full scarlet has been given to the cloth, the liquor still retains part of the cochineal, with a large portion of the mordant, and this is used for the lighter dyes; or, with the addition of fustic, madder, and other ingredients, it is employed for a vast variety of mixed, or, as they are called, degraded reds, orange, &c.

To dye a pound of wool Scarlet.—Boil it in a tin vessel, with something less than a quart of water: three drams of tartar, and an ounce and a half of cochineal: when the ebullition begins, add an ounce and a half of tin, and the whole to be boiled a quarter of an hour; the vessel is then taken from the fire, and the solution poured into a large caldron of boiling water, at the instant the cloth is immersed in it.

Dr. Bancroft recommends a method of dyeing scarlet in which a much smaller portion of cochineal produces an equal effect. He imagined scarlet, from his experiments, to be a compound colour, caused by about three-fourths of crimson or rose colour, and one-fourth of pure bright yellow. Hence he infers, that when the natural crimson of the cochineal is made scarlet by the usual process, a fourth of the colouring matter of the cochineal must be changed from its natural crimson to a yellow colour, by the action of the solution of tin. On this account, he introduced a bright yellow dye into the bath with the cochineal, and reduced the quantity of this more expensive ingredient. He found that a mixture of two pounds of sulphuric acid with three pounds of muriatic acid poured on fourteen ounces of granulated tin, with exposure to heat, produced a solution of tin, that had twice the effect of the common nitro-muriatic solution, at less than one-third of the expense, and which raised the colours more, without producing a yellow shade. For the yellow dye this excellent chemist used quercitron bark.

The Dutch manner of dyeing Scarlet.—Boil the cloth in water, with alum, tartar, rock salt, nitric acid, and pea flowers, in a pewter kettle; then put into the same kettle, starch, tartar, and cochineal, finely powdered, stirring or turning the cloth well about; thus you may, by adding more or less cochineal, raise the colour to what height you please.

General Observations for dyeing Cloth of a Red or Scarlet colour.—1st. The cloth must be well soaked in a lye made of alum and tartar; this is commonly done with two parts of alum and one part of tartar. 2d. For strengthening the red colour, prepare a water of bran or starch: bran water is thus prepared; take five or six quarts of wheaten bran; boil it over a slow fire in rain-water for a quarter of an hour, and then put it, with some cold water, into a small vessel, mixing it up with a handful of leaven (the sourer it is made the better); this causes the water to be soft, and the cloth to become mellow: it is commonly used in the first boiling, and mixed with the alum water. 3d. Agaric, is an ingredient used in dyeing of reds, but few dyers can give any reason for its virtue: as it is of a dry and spongy nature, it may reasonably be supposed, that it contracts the greasiness which may happen to be in the dye. 4th. Arsenic is a very dangerous ingredient; nitric or muriatic acid may supply its place as well. 5th. Scarlet is a variety of crimson colour: the nitric acid is the chief ingredient in the change; this may be tried in a wine glass, wherein a deep crimson colour is put: by adding drops of nitric acid to it, it will change into a scarlet. 6th. Observe that you always take one part of tartar to two parts of alum; most dyers prefer the white to the red tartar; but, however, in crimson colours, and others that turn upon the brown, the red tartar is chosen by many as preferable to the white.

To prepare the Cloth for dyeing of Scarlet.—First, take, to one pound of cloth, one part of bran water and two parts of river water; put into it two ounces of alum and one ounce of tartar; when it boils and froths, skim it, and put in the cloth; turn it therein for an hour; then take it out and rinse it.

To dye Cloth of a common Red.—Take, to twenty yards of cloth, three pounds of alum, one pound and a half of tartar, and one-third of a pound of chalk; put them into a kettle with water, and boil them; take six pounds of good madder, and a wine-glassful of vinegar; let them be warmed together; put in the cloth, and turn it round upon the winch till you observe it red enough; then rinse it out, and it will be of a fine red.

Another method.—Take four pounds of alum, two pounds of tartar, four ounces of white lead, and half a bushel of wheaten bran; put these ingredients, together with the cloth, into a kettle; let it boil for an hour and a half, and leave it to soak all night; then rinse it, and take, for the dye, one pound of good madder, two ounces of Orleans yellow, one ounce and a half of turmeric, and two ounces of nitric acid: boil them: turn the cloth with a winch for three quarters of an hour, and it will be a good red.

To dye a Crimson with Archil.—Put clean water into the kettle, and to each pound of silk take twelve ounces

ounces of archil; in this turn your silk, and wring it out; then dissolve, to each pound of silk, a quarter of a pound of alum, and as much white arsenic; in this liquor put the silk all night to soak, then wring it out; this done, take to each pound of silk two ounces of cochineal, two ounces of galls, two ounces of gum, with a little turmeric: in this boil the silk for two hours; let it soak all night, and in the morning rinse it out.

To dye Worsted, Stuff, or Yarn of a Crimson Colour.—Take, to each pound of worsted, two ounces of alum, two ounces of white tarter, two ounces of nitrous acid, half an ounce of pewter, quarter of a pound of madder, and a quarter of a pound of logwood; put them together in fair water, boiling the worsted therein for a considerable time: then take it out, and when cool rinse it in clean water; then boil it again, and put to each pound of worsted a quarter of a pound of logwood.

Another Method.—Take, to eight pounds of worsted, six gallons of water, and eight handfuls of wheaten bran, let them stand all night to settle; in the morning pour it clear off and filter it; take thereof half the quantity, adding as much clear water to it; boil it up, and put into it one pound of alum, and half a pound of tartar; then put in the worsted, and let it boil for two hours, stirring it up and down all the while it is boiling with a stick. Then boil the other half part of your bran water, mixing it with the same quantity of fair water as before; when it boils, put into it four ounces of cochineal, two ounces of finely powdered tartar; stir it well about, and when it has boiled for a little while, put in your stuffs: keep stirring it from one end of the kettle to the other with a stick, or turn it on a winch till you see the colour is to your mind; then take it out of the kettle, let it cool, and rinse it in fair water.

Another for Silk.—Take, to each pound of silk, a quarter of a pound of powdered Brasil wood; boil it up, and strain it through a sieve into a tub, and pour water to it till it is just warm: in this, turn your silk, which before has been prepared as has been directed; and when all the strength is drawn out, rinse, wring, and dry it.

Crimson may be produced either by dyeing the wool this colour at once, or by first dyeing scarlet and then changing the shade to that required. To dye crimson by a single process, somewhat different from that which has been described: a solution of two ounces and a half of alum, and an ounce and a half of tartar are employed for every pound of stuff, for each of which an ounce of cochineal is afterwards used in dyeing. A solution of tin may be employed, but in smaller proportions than for the dyeing of scarlet. To render the crimson deeper, and give it more bloom, archil, as we have seen, and potash are frequently used, but this bloom is extremely fugacious. Scarlet gives a crimson by means of alkalies, alum, and earthy salts. Crimson is the natural colour of the cochineal, and to produce it from a stuff dyed scarlet the stuff is boiled an hour in the solution of alum, the strength of which is to be regulated by the depth of the shade required.

To dye a fine CARNATION.—Take, to each pound of silk, after it is rinsed and dried, four pounds of safflower: put the safflower in a bag, and wash it in clean water till the water comes clear from it; then take the safflower out of the bag, press it between your hands, and rub it asunder in a clean tub; take to each pound of silk four ounces of potash; work it well together with the safflower; divide it into two parts; pour one part thereof into a close sack, that will keep the pot-ash from coming out, otherwise it will make the silk speckled; pour clear water over to draw the strength out of the safflower; then take, to each pound of silk, a quarter of a pint of lemon juice, divide that also into two parts, and put each to the two quantities of safflower; hang your silk well dried on clean sticks, and dip it in the first part of the liquor continually for an hour; then wring it well out and hang it again on sticks: having prepared the other part of the safflower as you did the first, dip it therein as before for the space of an hour; then wring it well and hang it up to dry in the shade, and you will have a fine colour.

A Carnation for Woollen.—Take four ounces of ceruss, three ounces and a half of arsenic, one pound of burnt tartar, one pound of alum; boil your stuffs with these ingredients for two hours; then take them out and hang them up; the next morning make a dye of two pounds of good madder, two ounces of turmeric, and three ounces of aqua-fortis.

To dye a Carnation on Silk or Cotton.—Take three pounds of alum, three ounces of arsenic, and four ounces of ceruss; boil your silk or cotton therein for an hour; then take it out and rinse it in fair water; after which make a lye of eight pounds of madder, and two ounces of muriate of ammonia; soak the silk or cotton therein all night; boil it a little in fair water, and put into it one ounce of pot-ash; then pour in some of the lye, and every time you pour the colour will grow the deeper, so that you may bring it to what degree you please.

Another Method.—Take, to one pound of silk, cotton, or yarn, one ounce of tartar, and half an ounce of white starch, boil them together in fair water; then put in one quarter of an ounce of cochineal, a quarter of an ounce of starch, and a quarter of an ounce of pewter dissolved in half an ounce of aqua-fortis, and mixed with fair water; when the water with the starch and tartar has boiled for some time, supply it with the cochineal and the above aqua-fortis; put in your silk or whatever you have a mind to dye, and you will have it of a fine colour.

Another Method.—Take one ounce of tartar; starch and lemon juice, of each half an ounce; cream of tartar a quarter of an ounce; boil them together in fair water, adding a quarter of an ounce of turmeric: put in half an ounce of cochineal, and, a little while after, one ounce of aqua-fortis, in which you have dissolved a quarter of an ounce of pewter, then put in your silk.

Method of dyeing Broad Cloth of a CARNATION *colour.*—Take liquor of wheaten bran, three pounds of alum, tartar two or three ounces; boil them, and then immerse in it twenty yards of broad cloth: after it has boiled three hours, cool and wash it; take fresh clear bran liquor in sufficient quantity, and five pounds of madder, boil as usual.

Of dyeing BLUE.—Blue may be dyed by woad alone, which would give a permanent, but not a deep blue; but if indigo be mixed with it a very rich colour will be obtained. The following is a method:

Of preparing a BLUE *Vat.*—Into a vat about seven feet and a half deep, and five and a half broad are to be thrown about 400 lbs. of woad broken in pieces. Thirty pounds of weld are boiled in a copper about three hours, in a sufficient quantity to fill the vat; when this decoction is made, twenty pounds of madder and some bran are to be added, and it is then to be boiled half an hour longer. This bath is to be cooled with twenty buckets of water; and after it is settled, the weld is to be taken out, and it is to be poured into the vat: all the time it is running into the vat, and for a quarter of an hour longer, it is to be stirred with a rake. The vat is then covered up very hot and left to stand six hours, when it is raked again for half an hour, and this operation is repeated every three hours. When blue veins appear on the surface of the vat, eight or nine pounds of quick-lime are thrown in: at the same time, or immediately after, the indigo is put into the vat, being first ground fine in a mill with the least possible quantity of water. When diluted to the consistence of thick pap, it is drawn off at the lower part of the mill, and thrown into the vat. The quantity of indigo depends on the shade of colour required. A vat which contains no woad is called an indigo vat. The vessel used for this preparation is of copper, into which is poured water, in the proportion of 120 gallons of this, six pounds of potash, twelve ounces of madder and six pounds of bran have been boiled: six pounds of indigo ground in water are then put in, and after carefully raking it the vat is covered, and a slow fire kept round it. Twelve hours after it is filled, it is to be raked a second time, which is to be repeated at similar intervals of time, till it comes to a blue, which will generally happen in forty-eight hours: if the bath be well managed it will be of a fine green covered with coppery scales, and a fine blue scum. In this vat the indigo is rendered soluble in the water by the alkali instead of the lime.

A second method for preparing a BLUE *Vat.*—Heat soft water in a kettle; put into it four or five handfuls of wheaten bran, together with four pounds of potash; when that is dissolved, boil it for an hour and add four pounds of madder; with this boil it for an hour longer, then pour the water into the vat; do not fill it by the height of a foot, and cover your vat; then set it with indigo and woad, of each six pounds, and two pounds of potash; put this into a small kettle in warm water, set it on a slow fire and let it boil gently for half an hour, stirring it all the while; then pour that to the other liquors already in the vat. To set a vat with indigo only, you must boil the first lye with potash, four or five handfuls of bran, and half or three quarters of a pound of madder; this boil a quarter of an hour, and when settled it will be fit for use. Then grind your indigo in a bowl with an iron smooth ball very fine, pouring on some of the lye and mixing it together: when settled, pour the clear into the blue vat; and, on the sediment of the indigo, pour again some of the lye; this you should repeat till you see the blue tincture is extracted clearly from it. It is to be observed, that the madder must be but sparingly used, for it only alters the colour and makes it of a violet blue, which, if you design to have, cochineal is the fitter for. The mixed colours in blue are the following: dark blue, deep blue, high blue, sky blue, pale blue, dead blue, and whitish blue. By mixing of blue and crimson, purple, columbine, amaranth, and violet colours are produced; and from those mixtures may also be drawn the pearl, silver, gridlin, &c. colours. From a middling blue and crimson are produced the following colours, viz. the pansy, brown grey, and deep brown. Care must be taken that in setting the blue vat you do not overboil the lye, by which the colour becomes muddy and changeable; be also sparing of the potash, for too much gives the blue a greenish and false hue.

Directions for setting another Blue Vat; with observations upon the management, both for Silk and Worsted.—Take half a bushel of clean beech ashes, well sifted; of this make a lye with three pails of river or rain water; pour it into a tub, and put in two handfuls of wheaten bran, two ounces of madder, two ounces of white tartar finely powdered, one pound of potash, half a pound of indigo, pounded; stir it all well together once every twelve hours, for fourteen days successively; when the liquid appears green on the fingers it is fit for dyeing; stir it every morning, and when done cover it. When you are going to dye silk, first wash the silk in a fresh warm lye; wring it out, and dip it into the vat. You may dye it of what shade you please, by holding it longer or shorter in the dye. When the colour is to your mind, wring the silk; and having another tub ready at hand with a clear lye, rinse your silk; then wash and beat it in fair water, and hang it up to dry. When the vat is wasted, fill it with the lye; but if it grows too weak, supply it with half a pound of potash, half a pound of madder, one handful of wheaten bran, and half a handful of white tartar; let it stand for eight days, stirring it every twelve hours, and it will be again fit for use.

Another Method for Woollen.—Fill a kettle with water, boil it up, and put potash into it; after it has boiled with that a little, put in two or three handfuls of bran; let it boil for a quarter of an hour and then cover it; take it off the fire, and let it settle. Pound indigo as fine as flour; then pour the above lye to it, stir and let it settle, and pour the clear lye into the vat; then pour more lye to the sediment, stir it, and when settled, pour that into the vat also; repeat this till the indigo

indigo is wasted. Or, take to a quarter of a pound of indigo half a pound of potash, a quarter of a pound of madder, three handfuls of borax; let them boil for half an hour, and then settle; with this lye grind your indigo in a copper bowl; put this in an old vat of indigo, or on a new one of woad, and it will make it fit for use in twenty-four hours.

Hellot describes two vats, in which the indigo is dissolved by means of urine. Madder is added to them; in the one vinegar is put, in the other alum and tartar, of each an equal weight to the indigo. It is probable the indigo is dissolved in them by the ammonia formed in the urine.

To dye Saxon BLUE.—Take four parts of sulphuric acid and pour them on one part of indigo, in fine powder: let the mixture be stirred some time, and having stood twenty-four hours, one part of dry potash in fine powder is added: the whole is to be again well stirred, and having stood a day and night, more or less water is added gradually. This colour derives its name from having been discovered at Grossenhayn, in Saxony, by the chemist Barth. To dye cloth with it, it must be prepared with alum and tartar: a greater or less proportion of indigo is put into the bath, according as the shade required is deep or light: for deep shades the stuff must be passed several times through the bath: lighter shades may be dyed after the deep ones, but they have more lustre when dyed in a fresh bath.

According to Chaptal, when wool is to be dyed in a blue vat, the operator fixes to the sides of the vat iron or copper hoops, which are fastened with cords to the hooks on the sides of the vat; the inner sides of these hoops are furnished with a net, and when wool is to be dyed, he puts above it another net thicker than the former. These preparations are necessary to prevent the cloth coming into contact with, or disturbing the deposition at the bottom of the vat. When the caldron is thus furnished, the stuff previously wrung out of tepid water is put into it, and kept a longer or shorter time according to the degree of strength that is to be imparted to the colour. When taken out it is wrung above the copper and exposed to the air. The green colour which it has imbibed in the bath is instantly changed by the action of the atmosphere. In dyeing Saxon blue according to this chemist, a mordant is used of three ounces and three quarters of alum and two ounces and a quarter of cream of tartar to one pound and a quarter of cloth. After being boiled in this composition an hour, the stuff is left in it about twenty-four hours longer. The colour bath is prepared by pouring into boiling water an ounce, or rather less, of the solution of indigo in sulphuric acid to one pound and a quarter of cloth, which is boiled in it twenty or thirty minutes, and after being taken out it is carefully washed.

Dark blues cannot be produced in the indigo vat: to obtain the *Turkish* blue, which is the deepest of all, it is necessary to immerse the silks in a very strong warm bath of savory before putting it into the vat. *Royal* Blue is also very deep and permanent, and to obtain this, cochineal is employed instead of savory. This last blue may be imitated by immersing the silk in a solution of one ounce and a half of verdigris to one pound and a quarter of silk; the silk is afterwards disposed in a bath of Indian wood, in which it assumes a blue colour, which is fixed by passing it through the vat. Silks to be dyed blue are usually boiled in a bath composed of 44 lbs. of soap to about 110 lbs. of silk; it is carefully washed, after which it is made into skeins and plunged into the vat till it has acquired the desired shade.

YELLOW is usually imparted to woollen substances by a decoction of woad, but as this plant yields its colouring principle with difficulty, alkalies are employed to assist in its extraction. Alkalies are chiefly used for this purpose in the dyeing of linen or cotton, and their place must be supplied by salt, sal-ammoniac, and alum, when wood is to be applied to animal substances which are dissolved in alkalies. Lime is sometimes used to heighten yellow colours. A good yellow of different tints may be procured by boiling woad with marine salt, lime, or alum: the salt produces the deepest shade: alum renders the colour brighter, ammonia imparts a greenish hue to the bath, tartar gives a very pale shade, and copperas changes it to a brown.

To dye Silk YELLOW.—Silks intended for a yellow colour are boiled in the proportion of about one pound of soap to five pounds of silk; they are afterwards washed, alumed, and exposed on rods. The yellow bath is prepared by boiling two pounds and a quarter of woad to the pound of silk about a quarter of an hour. This bath is strained through a sieve, and cooled till the hand can be kept in it, before the silk is immersed in the vat. A golden hue may be imparted to yellow by means of annotta.

To dye Silk of a POPPY *colour.*—The most beautiful red imparted to silk is that termed POPPY: this colour is procured by precipitating on stuff, bastard saffron held in a solution of potash. With this view, when the silk is washed and put on rods, citric juice is poured into the bath till it acquires a cherry colour. It is then well stirred, and the silk repeatedly let down into it till it has acquired a sufficient colour. To produce a full poppy colour the silk is wrung on coming out of the first bath, which it exhausts, and is then put into the second. Five or six baths are requisite to impart to it a *flame* colour. The poppy colour is heightened by putting the silk through tepid water acidulated with lemon-juice. Annotta, three or four shades paler than aurora is requisite for silks, before exposing them to the colouring principle of bastard saffron. The poppy colour communicated by this last dye may be imitated by Brazil wood.

To dye Silk of a STRAW YELLOW.—Take alum and rinse your silk well as before directed, then boil to each pound of silk one pound of fustic, and let them stand for a quarter of an hour: put into a tub large enough for the quantity of the silk, a sufficient quantity

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of that lye and fair water; in this rinse the silk; fill the kettle again with water and let it boil for an hour, and having wrung the silk out of the first liquor, and hang it on sticks, prepare a stronger lye than the first; in this dip your silk till the colour wished for is obtained.

Another Method.—Put into a clean kettle, to each pound of silk, two pounds of fustic, let it boil for an hour, then put in six ounces of gall; let them boil together half an hour longer. The silk, being alumed and rinsed, is turned about in this colour; then take it out of the kettle and wring it; dip it in potash lye and wring it out again; then put it into the kettle, let it soak a whole night, and in the morning rinse, beat it out, and hang it up to dry.

To dye Yarn of a Yellow Colour.—In a kettle of strong lye put a bundle of woad and let it boil, then pour off the lye, and take, to one pound and a half of yarn, half an ounce of verdigris, and half an ounce of alum; put it into a quart of brown Brasil wood liquor boiled with lye, stir it well together, and pour it in and mix it with the woad lye; in this soak your yarn over night, and it will be of a good yellow.

To dye Silk an Orange Colour.—After you have cleaned your kettle well, fill it with clean rain water, and take to each pound of silk four ounces of potash, and four ounces of Orleans yellow, sift it through a sieve into the kettle; when it is well melted, and you have taken care not to let any of the ingredients stick about the kettle, put in your silk, which before you have prepared and alumed as has been directed, turn it round on the winch and let it boil up; then take and wring it out, beat it, and rinse it; next prepare another kettle, and take to each pound of silk twelve ounces of gall-nuts; let the gall-nuts boil for two hours, then cool it for the same space of time, after which put in the silk for three or four hours, wring it out, rinse, beat, and dry it.

Another Orange Colour.—Soak the white silk in alum water as you do in dyeing of yellow: take two ounces of Orleans yellow, put it over night in water, together with one ounce of potash: boil it up, add to it, after it has boiled half an hour, one ounce of powdered turmeric; stir it with a stick, and after a little while put your alumed silk into it for two or three hours, according to what height you would have your colour, rinse it out in soap-suds till it looks clear, afterwards clear it in fair water, and dress it according to art.

A fine Brimstone Yellow for Worsted.—Take three pounds of alum, one pound of tartar, and three ounces of salt; boil the cloth with these materials for one hour; pour off that water, and pour fresh into the kettle; make a strong bath of weld; let it boil, then turn the cloth twice or thrice quickly upon the winch, and it will have a fine brimstone colour.

A Lemon Colour.—Take three pounds of alum, three ounces of ceruss, and three ounces of arsenic; with these ingredients boil the cloth for an hour and a half; pour off that water, and make a lye of sixteen pounds of yellow flowers, and three ounces of turmeric; then draw or winch your cloth through quickly, and you will have it of a fine lemon colour.

To dye an Olive Colour.—To dye this colour, observe the first directions for dyeing a brimstone colour; then make a lye of gall-nuts and vitriol, but not too strong; draw your stuff quickly through, three or four times, according as you would have it, either deeper or lighter.

To dye a Gold Colour.—Having first dyed your silk, worsted, cotton, or linen, of a yellow colour, take, to each pound of the commodity, one ounce of yellow chips, and of potash a drachm; boil for half an hour; then put in your silk, and turn it till the colour required is produced.

Weld is considered by most dyers as the yellow which unites beauty with durability in the highest degree.

To dye wool or woollen cloth YELLOW.—The wool is first cleansed, and then passed through a bath of about 4 parts alum, and 1 of tartar, to every 16 parts of wool. It is then dyed in the weld bath, for which from 3 to 4 parts of weld are used to one part of wool. A golden yellow, with more or less orange, is given by a weak madder after the welding. Silk is dyed of a golden yellow generally with weld alone. The stuff is first boiled in soap water, alumed and washed, then passed twice through a weld bath in which, the second time, some alkali is dissolved, which gives a rich golden hue to the natural yellow of the plant. A small quantity of annotta still further deepens the colour. The solutions of tin apply well to silk, and with weld give it a bright clear yellow.

To dye cotton YELLOW.—It is first cleansed with wood-ashes and water, rinsed, alumed, and dried, and then passed through a yellow bath, in which the weld at least equals the cotton in weight. When the colour is sufficiently taken, the cotton is thrown into a bath of sulphate of copper and water, and kept there for an hour, after which it is boiled in a solution of white soap, and finally washed and dried.

If a deeper jonquil yellow be required, the aluming is omitted, and instead, a little verdegris is added to the weld bath, and the cotton finished with soda. In giving the lively greenish lemon yellow, weld is preferred to all other materials.

Wool may be dyed a fast yellow colour with quercitron, by being first cleansed, and then boiled for an hour with one-sixth of its weight of alum in water; then without rincing, transferred into the vessel containing a decoction of as much quercitron bark as there was used of alum, and turned through the boiling liquor over the winch till the colour appears to have taken.

Chalk or alkali is of great service in yellow-dyeing, whether with weld, quercitron, or any other colour, when the mordant is alum, as this addition helps to bring out and heighten the dye.

The salts of tin, being powerful mordants for almost every

every colouring matter, may be employed with advantage in dyeing yellow of the finest colours. Dr. Bancroft recommends the murio-sulphate of tin, of which 10lbs. with as much quercitron bark, are sufficient to give the highest orange yellow to 100lbs. of cloth. The process is as follows:

First, tie up the bark in a bag and put it into the boiler, and when boiled in water a few minutes, let the tin solution be added, and the mixture well stirred; the cloth, previously scoured and wetted, is passed briskly through the liquor over a winch for about a quarter of an hour.

Of Blacks.—The black commonly given to all kinds of stuff, is that which is produced by some vegetable astringent, particularly galls, with the salts of iron, but many circumstances must be attended to, in order to produce a full and good colour. Wool takes this kind of black with much more ease than linen or cotton. Hellot's process is as follows:

For every 50lbs. of cloth take 8lbs. of logwood, and as much galls, both bruised or powdered, tie them loosely in a bag, and boil in a moderate sized copper for about twelve hours with sufficient water. Put one-third of this decoction, with a pound of verdigris, into another copper, and soak the cloth in it for two hours, keeping the liquor scalding hot, but not boiling. Take out the cloth, add to the same copper another third of the first decoction, with 4lbs. of vitriol or sulphate of iron, and bring it again to a scalding heat, and soak the cloth in it for an hour, stirring it well all the time. Then take out the cloth, and add the remaining third of the decoction with 8 or 10lbs. of sumach, boil the whole, lower the heat with a little cold water, add a pound more of vitriol, and return the cloth for an hour longer. The cloth is then washed and aired, and returned to the bath again for an hour, after which it is well washed in running water and fulled. It is, lastly, passed through a yellow bath of weld for a short time, to give a higher gloss and softness to the black.

The common blacks, however, are given in a much simpler manner, the stuff, previously dyed blue, being first soaked in a bath of galls and boiled for two hours, and then passed through another bath of logwood and vitriol at a scalding heat, after which it is washed and fulled.

To dye Woollen Stuffs of a Black colour.—Fine cloths, and such stuffs as will bear the price, must be first dyed of a deep blue, in a fresh vat of pure indigo; after which, boil the stuffs in alum and tartar; then dye in madder; and, lastly, with galls of Aleppo, sulphate of iron, and sumach, dye it black. To prevent the colour soiling when the cloths are made up, they must, before they are sent to the dye-house, be well scoured in a scouring mill. Middling stuffs, after they have been prepared by scouring, and drawn through a blue vat, are dyed black with gall-nuts and vitriol. For ordinary wool, or woollen stuffs, take of walnut-tree branches and shells, a sufficient quantity; with this boil your stuff to a brown colour, then draw it through the black dye, made with the bark of elder, iron or copper filings, and Indian wood.

To dye Linen of a Black colour.—Take filings of iron, wash them, and add to them the bark of elder-tree: boil them up together, and dip your linen therein.

To dye Woollen of a good Black.—1st. Take two pounds of gall-nuts, two pounds of the bark of elder-tree, one pound and a half of yellow chips, boil them for three hours; then put in your stuff, turn it well with the winch, and when you perceive it black enough, take it out and cool it. 2. Take one ounce and a half of muriate of ammonia, with this boil your stuff gently for an hour long, turning it all the while with the winch; then take it out again and let it cool. 3. Take two pounds and a half of vitriol, a quarter of a pound of sumach; boil your stuff therein for an hour; then cool and rinse it, and it will be of a good black.

Another Black colour for Woollen.—For the first boiling, take two pounds of gall-nuts, half a pound of Brazil wood, two pounds and a half of madder; boil your cloth with these ingredients for three hours, then take it out to cool; for the second boiling, take one ounce and a half of sal ammoniac; and for the third, two ounces and a half of vitriol, three quarters of a pound of Brazil, and a quarter of a pound of tallow.

Another Black colour for Plush.—Put the following ingredients into a large vessel; viz. eight pounds of elder bark, eight pounds of sumach, twelve pounds of oaken chips, nine pounds of sulphate of iron, two pounds of wild marjoram, six pounds of tile-dust, some waste of a grindstone, six pounds of walnut leaves, half a pound of burnt tartar, two pounds of salt, four pounds of woad; on these pour boiling water till your vessel is full: your plush, after it is well boiled and cleansed, must be well galled, by boiling it in one pound and a half of sumach, eight ounces of madder, two ounces and a half of burnt nitre, half an ounce of muriate of ammonia, one ounce and a half of sulphate of iron, half an ounce of burnt tartar; then take it out, and let it dry, without rinsing it. Then fill the kettle with the above liquor, and boil and dye your plush in the manner as you do other stuffs, turning it round with the winch. When the colour is to your mind, take out the plush, let it cool, and rinse and hang it up to dry.

To dye Silk of a good Black.—In a kettle containing six pails of water, put two pounds of beaten gall-nuts, four pounds of sumach, a quarter of a pound of madder, half a pound of antimony finely powdered, four ox galls, four ounces of gum tragacanth dissolved in fair water, fine beaten elder bark two ounces, and one ounce and a half of iron file-dust; put these ingredients into the water, and let them boil for two hours; then fill it up with a pailful of barley-water, and let it boil for an hour longer; put in your silk, and boil it for half an hour slowly: then take it out and rinse it in a tub, with clean water, and pour that again into the kettle; the silk you rinse quite clean in a running water, then hang it up, and when it is dry, put it in the copper again; boil it slowly for half an hour, as before; then rinse it in

in a tub, and again in rain water; when dry, take good lye, put into it two ounces of potash, and when they are dissolved, rinse the silk therein quickly, then in running water; this done, hang it to dry, and order it as you do other coloured silks. This colour will also dye all sorts of manufactured woollen stuffs. To give the black silk a fine gloss, you must, before the last dipping, put in, for each pound, one ounce of isinglass dissolved in water.

Of Green. Having given an account of some processes for dyeing the simple colours, red, blue, yellow, and black, we may touch on those that are compound, so called as being produced in dyeing by mixtures of the simple colours, though in certain cases substances are found which produce compound colours without any addition.

To dye woollen green, either a blue or a yellow dye may be first given to it, but the first is generally used, because the yellow dye of the stuff would injure the blue bath. The intensity of the blue must ever be proportioned to the shade of green required. When the blue dye is given, the yellow is communicated by some of the processes already described. The cloth having the proper ground, is washed at the fulling mill, and boiled as for the common process of welding, but when the shade is to be light, the proportion of salts should be less. In this case, the quantity of weld used should also be less, but for all other shades it should be greater than for dyeing simple yellow.

Saxon greens are obtained from sulphate of indigo. From six to eight pounds of quercitron bark, enclosed in a bag, should be put into the bath for every hundred pounds of cloth, with only a small proportion of water, just as it begins to grow warm. When the water boils, six pounds of murio-sulphate of tin should be put in, and in a few minutes after, about four pounds of alum; these having boiled five or six minutes, cold water should be added, and the fire diminished, so as to bring down the heat of the liquor nearly to what the hand is just able to bear: after this, as much sulphate of indigo is to be added as will suffice to produce the shade of green required, taking care to mix it thoroughly with the bath. The cloth having been previously scoured and moistened, should then be expeditiously put into the liquor, and turned very briskly through it for a quarter of an hour, that the colour may apply itself evenly in every part. By this method beautiful greens may be dyed in half an hour.

A fine Green for dyeing Silk.—Take, to one pound of silk, a quarter of a pound of alum and two ounces of white tartar; put them together in hot water to dissolve, then put in your silk, and let it soak all night; take it out the next morning, and hang it up to dry; then take one pound of fustic, and boil it in four gallons of water for an hour; take out the fustic, fling it away, and put into the kettle half an ounce of fine beaten verdigris; stir it about for a quarter of an hour, draw it off into a tub, and let it cool; then put into that colour an ounce of potash; stir it together with a stick; dip into it your silk, till you think it yellow enough; rinse it in fair water, and hang it up to dry, then dip it in the blue vat, till you think it enough; rinse it again, and beat it over the pin, and hang it up to dry: thus you may change the shades of your green, by dipping either more or less in the blue or yellow. For the green, take, to one pound of silk, three ounces of verdigris beaten to a fine powder, infuse it in a pint of wine vinegar for a night, then put it on the fire; when hot, stir it with a stick, and keep it from boiling; in this put your silk two or three hours, or if you would have it of a light colour, let it soak but for half an hour; then take scalding hot water, and in a trough, with soap, beat and work up a clear lather; in this rinse your silk, then hang it up to dry; rinse it again in river water, beat it well, and when it is well cleaned and dried, dress it.

To dye Linen of a Green colour.—Soak your linen overnight in strong alum water, then take it out and dry it: take woad, boil it for an hour; take out the woad, and put in one ounce of powdered verdigris, according to the quantity you have to dye; stir it together briskly, with the linen; then put in a piece of potash the size of an hen's egg, and you will have your linen of a yellow colour, which, when dried a little, and put into a blue vat, will turn green.

Cotton and linen are, in another process, scoured in the usual way, and then first dyed blue: after being cleaned, they are dipped in the weld bath to produce a green colour. As it is difficult to give cotton velvet an uniform colour in the blue vat, it is first dyed yellow with turmeric, and the process completed by giving it a green by sulphate of indigo.

The different shades of olive, &c. are given to cotton thread, after it has received a blue ground by galling it, dipping it in a weaker or stronger bath of iron liquor, then in the weld bath, and afterwards in the bath with sulphate of copper; the colour is, lastly, brightened with soap. Yellow colours are rendered more intense by means of alkalies, sulphate of lime, and ammoniacal salts, but they become fainter by means of acids, and solutions of tin and alum.

To dye a Grey colour.—Grey is a middle colour, between black and white, which, beginning with a white grey, approaches by degrees to a black grey: it may be observed, that if the black colour was to be prepared only of gall-nuts and sulphate of iron, it would procure but an indifferent grey, but if to these ordinary ingredients for dyeing of stuffs, you add some Indian wood, you may procure white grey, pearl colour, lead colour, whitish grey, iron grey, black grey, brown grey, &c. Some of these colours require a little tincture of woad.

To dye a Brown-red colour either on Silk or Worsted.—First, after you have prepared your silk or worsted, in the manner directed for dyeing of red colours, boil it in madder; then slacken the fire, and add to the madder liquor some black colour prepared as has been shewn: then stir the fire, and when the dye is hot, work the commodities you have to dye therein, till you see them dark enough. But the best way to dye this colour is

is in a blue vat; therefore choose one either lighter or darker, according as you would have your colour, then alum and rinse your silk in fair water; this done, work it in the kettle with madder, till you find it answer your purpose.

Another.—Put into a kettle of hot water a handful of madder, stir it together, and let it stand a little: then take the woollen stuff, wet it first, then let it run over the winch into the kettle, turning it constantly; if you see it does not make the colour high enough, add a handful more of madder, rinsing the stuff or silk sometimes, to see whether it is to your liking. Then put some black colour into the kettle, mix it well together, and when hot, turn your silks or stuffs with the winch, and dye them either of a blacker hue by adding more black, or a redder by putting in less.

To dye a Brown colour.—Brown colours are produced by the root, bark, and leaves of walnut trees, and also by walnut shells; china-root might also be used for brown colours, but it being of a disagreeable scent, it should only be used for hair colours in stuffs, for which, and the olive colours, it is of more use: the best browns are dyed with woad and walnut tree root.

A Nutmeg colour, on Stuffs.—Take three pounds of alum, and half a pound of tartar; put this into a kettle of water, and boil your stuff for an hour and a half, then take it out to cool. Take one pound and a half of yellow flowers, three pounds of madder, one pound of gall-nuts; put them, together with the stuff, into a kettle; boil and turn it with a winch till it is red enough, and take it out to cool; then take two pounds of sulphate of iron, which before is dissolved in warm water, put it into the kettle, and turn the stuff till the colour is to your mind, then rinse it out.—Or, take half a bushel of green walnut shells, or walnut tree root, to a kettle of water, and when it begins to boil, put in the stuff, over a winch; turn it about three or four times, then take it out and let it cool; after it is cold, boil the liquor again, and put the stuff in; turn it for half an hour, and take it out and let it cool; then put one pound of gall-nuts, three pounds of madder, together with the stuffs, into the kettle; let it boil for an hour; take it out and let it cool again; take one pound of sulphate of iron, put it in, stir it well about, then put in again the stuffs over the winch; turn and boil it till you perceive your colour deep enough, then take it out and rinse it.

Of dyeing with Madder.—It has been a common rule to take, to eight pounds of madder, one pound of tartar. Alum and tartar are used for preparing the commodities, for attracting and preserving the colour. Potash heightens the colour very much, as does bran water; brandy is of peculiar use; it attracts the colour, makes it look clear and fine, and frees the subtillest particles from its dregs and impurities. Some dyers, and indeed most, ascribe the same virtue to urine; but although it may be of much use when fresh, it is highly prejudicial to light colours when stale, for it causes the colour to be of a heavy and unpleasant hue: this ought, therefore, to be a caution to such as would dye light and tender colours. The experiment may be tried in a glass of clean water, in which litmus, being first dissolved and filtered, is poured in: if to this liquid, which is blue, you pour some muriatic acid, it will turn red; and mixing it with a little dissolved alkali, it will resume its former colour: if you put too much of the latter, the liquid will turn green: and thus you may change the colour, by adding more or less of either the one or the other ingredient to it.

To dye Silk of a Madder Colour.—Prepare it as has been directed under the article of dyeing silk "a crimson colour." This done, put a pailful of river water into a kettle, together with half a pound of madder; boil it for an hour, and take care it boils not over, then let it run off clear into another vessel, stirring into it one ounce of turmeric; then put in your silk, let it lay therein till cold, then wring it out and beat it; this done, take half a pound of good Brazil wood, boil it in bran water for an hour, clear it off in another vessel, and put in your silk; rinse it out in soap-lye, and then in running water; after which dry and dress it.

Another method.—After you have prepared your silk for dyeing, hang it on sticks, and to each pound of silk take eleven ounces of madder, and four ounces of nut-galls; put these into a kettle with clean rain-water; hang in your silk, and augment the heat till it is ready to boil; then turn your silk in it for half an hour, and prevent its boiling, by lessening the fire: after this, rinse and beat it out; hang it again on sticks, in a tub with cold water, in which you have put some potash; this gives it beauty: then rinse and dry it. How this madder is made use of for dyeing of worsted or stuffs, has been shewn already.

Of the Mixture of Colours.—Although we have touched on this subject already, yet we shall say something more about it. Pure or unmixed colours are rarely found in nature. *Red* is uniformly found intermingled with yellow; scarlet and madder colours are composed of these two principles. *Indigo*, which appears to furnish the most perfect blue, is always debased by a yellowish matter, which is removed by ebullition. Exclusively of these natural mixtures, the artificial shades formed out of them are extremely numerous: we shall only refer to a few of the leading ones, which may be comprehended in the following classes. 1. A mixture of blue and yellow, which produces all the intermediate shades between the yellowish green and the dark green verging to black. 2. A mixture of red and blue, which comprehends all the shades from a deep violet colour to a lilac. 3. A mixture of red and yellow, which embraces all the shades from a scarlet colour to that of musk and tobacco.

1. To form on wool the mixture of blue and yellow, we first impart to the stuff the blue ground: and the green so produced becomes deeper as the blue is more intense. When the cloths are taken out of the blue vat, they are boiled in the same manner as those intended to be dyed by woad, and for this purpose a

decoction of that substance is prepared in which the stuffs are immersed. Green is rendered brown by logwood and a small portion of iron. Green is transferred to cotton by a nearly similar process, but instead of the mordant composed of alum and tartar, the acetate of alumine is used.

To impart a Green to Silk.—After boiling it with soap, it is strongly alumed; then slightly washed in running water, and stretched in a woad bath. To render the colour darker and to vary its shade, a decoction of Indian wood of fustic, annotta, &c. is introduced into the woad bath. Savory is preferred to woad, when the blue vat is employed, because the colour which it imparts inclines naturally to green. The green obtained by the solution of indigo in the sulphuric acid, is, as we have seen, called Saxon green; it is more brilliant but less durable than that which has just been described. This cloth is prepared as in dyeing with woad; after it has been washed, it is boiled in the same bath an hour and a half, with yellow chips. When the heat of the bath is moderated so that the hand can bear it, we introduce one pound and a quarter of the solution of indigo for every eighteen yards of cloth; the cloth is then to be immersed in it, turned at first rapidly, but afterwards more slowly. The cloth must be taken out before the bath begins to boil. Woad may be substituted instead of the yellow wood, and the shades varied at pleasure, by varying the proportions of the ingredients. When the blue has been dyed in the vat, it is more permanent than the yellow; whence it happens, that the green colour changes to blue in the course of time; while on the contrary, when the blue is given by the solution of indigo in sulphuric acid, the yellow is most durable.

2. The combination of red and blue forms the violet colour, and the shades dependent upon it. This combination exists naturally in logwood: it is likewise developed in most of the lichens by fermentation, but it is not fixed in either of these two states.

To give a good violet tint to woollen cloth, it is slightly dyed in a blue vat; after which it is boiled, during an hour and a half, in a bath composed of three ounces and three quarters of alum and about half an ounce of alum to one pound and a quarter of cloth. A bath is then prepared of one ounce and a half of cochineal and half an ounce of tartar, in which the cloth is boiled an hour or more, when it assumes a blue colour. By the addition of alum and tartar to the violet bath, we may obtain all the inferior shades of lilac, dove, mallows, &c.

The violet colours imparted to silk are divided into two kinds, the true and false; to produce the first, the silk is dyed in the same manner as crimson, except that neither tartar nor the solution of tin are mingled with the bath. To produce a very beautiful violet three ounces of cochineal is employed to one pound and a quarter of silk. The stuff is then passed through a weaker vat, and to impart still greater beauty to the colour, it is afterwards immersed in a savory bath.

The most beautiful *false* violets are prepared with savory, they are readily known by the property which they possess of becoming red by the action of acids. A good violet may be given to cotton, by dyeing it with madder, and afterwards passing it through a blue vat. The beauty of this colour depends on the meagreness of the red.

The *true* violet is only imparted to cotton by combining oxide of iron with madder red. The iron must be applied to the cotton previously to its being immersed in the madder bath. It is not easy to obtain this colour uniform, because the iron deposited on the cotton is apt to become unequally oxydated in drying. To obviate this, the cottons should be washed after receiving the mordant, and be plunged into the madder bath while wet. All the different shades may be obtained by combining alum with the sulphate of iron, calcined to redness, in different proportions, in forming the mordant for violets.

When a very beautiful violet is the object, it is necessary, on taking the cotton out of the oil, to pass it into the mordant already described; then to wash it with care, and plunge it into a cold madder vat; after which it must be again washed, immersed into a new bath of madder and boiled for an hour, and, lastly, brightened by washing with soap.

3. Yellow, intimately combined with red, may be variously modified. By boiling fustic in a scarlet bath, heightened by a small portion of cream of tartar, and the composition of tin, we may produce successively a pomegranate, orange, and jonquil colour. The fustic is added to the cochineal, in proportion to the shade required. The addition of a little madder will produce a gold colour.

Madder red unites with yellow, and gradually changes it from an orange to the other different shades. If instead of the bright yellows we use plants giving out a brownish colour, such as many astringent vegetables, we obtain more solid, but less brilliant colours. Thus, hazel roots, sumach, &c. produces tobacco and musk colours.

Maroon and wine colours may be imparted to silk by logwood, fustic, &c.: a decoction of fustic forms the foundation of the bath, to which is added about a fourth part of the juice of fernambucca, and an eighth of logwood. The silks are to be alumed before they are immersed in this bath. If brown shades are required, the Indian wood is employed in a greater proportion than the Brazil wood.

Of the Art of Transposing, or Changing Colours.—Most colours, when transferred to stuffs, undergo or suffer some change. This art is termed, by dyers, changing or turning the bath. This is one of the most delicate and interesting operations connected with dyeing. In it resides nearly all the mystery of the art. We can here only briefly sketch the principal changes, or alterations, that may be produced on a colour, by the action of colourless bodies. For more particular information on the processes of dyeing, we must refer the

the reader to those works which treat professedly on the subject.

The acid solution of tin reddens cochineal, and brightens the colour of its decoction. Cream of tartar renders of a brighter yellow the same colouring principle. The solution of alum changes a scarlet into a crimson. Hence it is that cloth, to which alum has been applied as a mordant, assumes a crimson colour in the scarlet bath. The scarlet is converted by the alkalies into violet. The red of cochineal is changed by sea salt into lilac shades, which approach to a blue. Sal ammonia deepens it, without depriving it of the red. Gypsum changes the red into blue. The red of cochineal is converted by copperas into violet. Hot water renders it blue, by impairing the vivacity of the red. The madder red is susceptible of the same modifications, though less perceptibly. The acids render it yellow, and change it to orange. Lime, and other calcareous salts, impart to it a vinous colour. The alkalies are employed to give a rose tint to the red of Brasil wood, and to form a false crimson upon silk. The alkalies give a yellow shade to the red of carthamus, or bastard saffron. Its colour may be restored by citron or lemon juice. The alkalies develop the colour in all vegetables employed to furnish a yellow dye. A solution of potash is even used to transfer to cotton the colouring principle of woad. The alkalies disguise the red colour which is combined in the annotta with the yellow; the acids destroy or counteract their effect, so that by the aid of these two salts, may be communicated to the annotta all the intermediate shades of colour, from the lightest yellow to an orange. The alkalies convert into a permanent orange the yellow procured from wool and silk by the nitric acid. For this purpose it is sufficient to pass these two stuffs, coloured by the acid, into a caustic alkali. By employing the acid at 25, or 28 degrees, a very beautiful colour is obtained. The alkalies are also employed to change the violet procured from Brazil and Indian wood; they improve the colour of the Brazil, and render brighter the violet of the logwood.

Silk prepared as for the true violet, may be changed into purple, by means of a little arsenic introduced into the cochineal bath. What relates to the art of changing, or transposing colours, may, in general, be reduced to very simple principles. 1st. When the reds are pure, the acids render them pale, or of an orange tinge, by assimilating them to a yellow colour. Alum, cream of tartar, the solution of tin, and acids, produce the same effect. 2. When the reds are mixed with a portion of blue, not possessing much fixity, the acids exalt the colour, by destroying or reddening the blue. Examples of this are furnished by fernambucca, and by nearly all the false vegetable reds. 3. The alkalies destroy the resinous reds, and develop the yellow which is united with them. The red tint of the annotta, as well as that of the carthamus, is effaced by them; acids restore it. 4. Alkalies restore the violet colours, reddened by acids, with greater intensity than they formerly possessed. 5. Sea salt, and all the calcareous salts, change the reds into a bluish crimson. 6. Iron, and all its combinations, impart a brown tint to red and yellow colours. Thus are produced all the different browns, which are at present so much in vogue.

Of the Exaltation of Colours.—The beauty of colours depends unquestionably on making a proper choice of materials; but in the mode of combining and heightening them, consists the art of dyeing. Washing improves the colour, by depriving the stuff of the colouring matter uncombined with it. It ought to be performed in clear and running water. The alkalies are employed to heighten certain colours. Thus, for example, in order to impart greater brilliancy to the Adrianople red, the cotton after maddering, is boiled on a lye of soda for twenty-four or thirty-six hours; after which it is washed and again boiled in a solution of soap. The violet colours transferred to cotton by the oxyd of iron and madder are heightened and improved in a similar manner. The colour, which appears a black on taking the cotton out of the bath, becomes bright, and forms a beautiful violet. It may be remarked, that the violet is changed into red by the action of alkalies, and into blue by that of soap. The acids likewise prove useful, by putting the poppy-coloured silks through tepid water acidulated by citron juice, the colour is rendered more brilliant and pleasing to the eye. The orange extracted from annotta is heightened and improved by the citric acid. All the acids destroy the violet colour which the cochineal sometimes assumes on wool, and exalt it to the shade of scarlet. They render the madder red slightly yellow. M. Hausmann proposes to pass the cottons on being out of the blue vat, into a water acidulated by the sulphuric acid, having ascertained that the colour was by this means rendered more intense. Blacks, transferred into a saponaceous solution, or into water agitated for a considerable time with a little oil, assume a deep red colour. The drying of stuffs in the sun, or in a clear day, spoils or destroys their delicate and lively colours. Drying in the shade preserves them.

We shall now conclude the article with an account of Calico-printing, for which we shall be indebted chiefly to Aikin's valuable Dictionary of Chemistry and the Arts.

Calico-Printing.—"To apply a coloured pattern on a white or coloured ground two general methods appear practicable; the one, to weave the pattern into the cloth with threads dyed of the requisite colours, the other to devise some method of topical dyeing, which shall, like a picture, confine the desired colours to those parts only that are figured by the intended patterns. The former is the delicate business of the embroiderer or the tapestry weaver; the latter is the ingenious art of the calico-printer. The history of this art and the detail of the vast variety of processes employed in producing the various coloured patterns, it would be superfluous to enter into, especially as most of what has been described of general dyeing applies (as far as the chemical

mical principles of the art are concerned) to topical dyeing. A few examples, therefore, of the peculiar manipulations of calico-printing will suffice. It is particularly, though not entirely, with the adjective colours, or those that require a mordant, that calico-printing is concerned, as this very circumstance affords a ready method of giving a permanent colour only to the pattern part; for if this latter only is impregnated with the mordant, and the whole cloth is then uniformly dyed, the natural effect of exposure to sun and air will be to discharge all the colour from every part of the cloth except where it had previously received the mordant, and thus a coloured pattern will be produced on a white ground. This partial application of mordants therefore, followed by general dyeing, constitutes the greater part of calico-printing, besides which, however, a further variety of application often occurs as sometimes colours themselves are painted or pencilled in to assist the general effect, which therefore require no subsequent operation; and occasionally other contrivances are used to fix, or alter, or discharge colours, according as the proposed pattern may require it. Two mordants are more particularly used by calico-printers, though equally serviceable in general dyeing; the one is acetite of alumine with a portion of alum, the other is a solution of iron in some vegetable acid. The acetite of alumine is always made by double decomposition of alum and sugar of lead, but the proportions of each vary much according to circumstances, and probably to the fancy of the colour mixer. In general, three pounds of alum (or in that proportion) are thrown into a barrel, and when dissolved, a pound, to a pound and a half of sugar of lead are added, and the whole frequently stirred during two days. On settling, a clear liquor is found at top, which consists of acetite of alumine, but still containing much undecomposed alum, and a dense white sediment remains at bottom, which is sulphate of lead. The clear liquor is the part used for the mordant, but previously two ounces of pearl-ash and as much chalk are added, more entirely to neutralize any excess of acid, and partly to decompose the solution; for though the mordant must be in a saline state entirely to fix itself to the fibres of the cotton, it should seem that the true intermedium between the cotton and the dye is the alumine, and not the acids that hold it in solution, and hence the weaker the adhesion of these is to the alumine, the stronger will be the triple union between the colour, the earth, and the cotton fibre. The other mordant constantly in use with the printers is a solution of iron in vinegar, sour beer, pyroligenous acid, or other vegetable acids, and which therefore is chiefly an acetite of iron mixed with a portion of tartrite, perhaps gallate, and other salts of this metal. To make these mordants fit for printing, and give them such a consistence as will enable them to dry in a figured pattern without running into the adjoining parts, they are thickened with paste to the consistence of jelly; and when to be used, this jelly is squeezed through a very fine sieve by a particular and simple contrivance, on the surface of which it lies as a thin coating convenient to be transferred to the printing blocks. The mordant, when naturally colourless, is a little tinged with Brazil wood (which being a very fugitive dye does not impair the general effect) that the workmen may see the impression on the cloth and fix the pattern with accuracy. The instrument by which the impression is given (or what answers to the types in the printing of books) is a piece of hard wood, generally holly, about a foot long, on which the pattern is carved, nearly as in wood engraving, and is strengthened at the back with a thicker piece of oak glued on. The parts of the pattern that are to receive a large body of colour, and consequently require a corresponding quantity of mordant are given by pieces of old hat inlaid into the block which are found to take up the mordant in a more uniform way than any other material. Of late years also some of the finer patterns are given by sheet copper fixed on a block-like filigree work, which gives a finer and sharper line to the figured pattern. Fine work is sometimes given still more expeditiously by engraved copper-plate and the rolling press, as in common picture-engraving. The general process of the simple kind of calico-printing therefore, is the following: the cotton cloth, previously bleached with alkali and much washing, and calendered to smooth the surface, is stretched on a long table covered with woollen cloth, when the printer first lays the block on the sieve that contains the mordant, then applies it steadily on the cloth, and strikes it a smart blow on the back with a wooden mallet to give a strong impression. This he repeats successively, each time carefully laying the block in the proper direction so as not to overlap the last impression, till the whole is finished. In this way the patterns are impressed with one or more kinds of mordant as may be required; after which the cloth is strongly dryed in a stoved room, that both fixes the mordant more firmly to the cotton, and *volatilizes* much of the acetous acid in fumes very sensible to the smell. When dry, the cloth is taken to a cistern containing very warm water, in which cow-dung is diffused, and there it is worked about to dissolve out the paste and other superfluous part of the mordant, sufficient being yet left firmly united to the fibres of the cloth to fix the dye in the subsequent process. The cloth is then rinced and thoroughly cleaned, after which it is dyed in the usual way. The cloth comes out of the dyeing cistern entirely coloured (yellow, for example, when the dye has been weld); it is then again washed with water, boiled with bran and water, alternating with exposure to air on the bleach field, and other bleaching processes; till, at last, all the colour of the ground has disappeared, and that only remains which has been fixed to the pattern by the mordant."

ENGINEERING.

ENGINEER civil, in contradistinction to the same profession attendant on military works, is a person of considerable importance in society: his employ embraces pre-eminently canals and their attendants, reservoirs, locks, basons, aqueducts, tunnels, bridges, docks and buildings in water, erecting beacons and light-houses, the cutting and forming roads, making iron rail roads, &c. &c. To make the expert engineer requires considerable talent in the individual, joined to great personal firmness, with a cautious enterprise. He should be a mathematician of the first order, with a ready aptitude of extending its powers to practical purposes, experienced in local nature, with science and command competent to assist and improve her, so as to effect all the multiplied wants of a great commanding and powerful people.—The cutting of canals is the first in order, and is of a very early date; for we find the Cnidians, a people of Asia Minor, projecting an undertaking of this nature: they wished the isthmus, which joined their territory, to connect itself with the continent. The oracle was consulted, and it was interdicted. (Herodotus, l. i. c. 174.) Basins and canals were formed in Bœotia, says Strabo, supplied by the lake Copais. The great river Euphrates was connected with the Tigris by means of a canal. A branch was also formed by Trajan near Coche, to join the same river. The Greeks, as well as the Romans, formed the design of making a canal across the Isthmus of Corinth, which joins Achaia, for the purpose of obtaining a passage by the Ionian sea. A similar plan was projected between the Euxine and Caspian seas. The Roman generals were fully impressed with the utility of canals, of which they executed many, as the ruins now existing demonstrate. They connected the Rhine with the Iosel, and also the former river with the Moselle. Savary says, the canals in Egypt amounted in number to eighty, but they were more for the purpose of irrigation than communication. The Nile was joined to the Red Sea by an artificial channel; the work was commenced by Necos, who was followed by Sesostris and Darius; the latter relinquished the undertaking on the information reaching him that the Red Sea being so much above the level of the land in Egypt, it would be difficult if not impossible to prevent the overflowing of the banks, and consequent inundation of the country. The alarm was just; but the engineer would have been but little acquainted with his subject not to have shewn the practicability of avoiding such a calamity. Under Ptolomy the Second the undertaking was completed. Its width was upwards of 100 cubits, reckoning 22 inches to each cubit; and in its depth sufficient to allow of the navigation of the largest vessels. By this canal India was enriched with the commerce of Egypt, Persia, and the coast of Africa. China, in her institutions hostile to art, has nevertheless encouraged the making of canals; and their convenience having aided in supplying a ready transit of her commodities she has, more perhaps from cunning than a wish to develope the powers of the human mind, intersected her country with them. The canal which runs from Canton to Pekin is in length upwards of 800 miles, and was executed about 700 years since: it has no locks, tunnels, or aqueducts, and when stopped by mountains or other impediments, they have recourse to a rolling bridge, and sometimes to inclined planes. These rolling bridges consist of a number of cylindrical rollers which turn easily on pivots, and are sometimes put in motion by a windmill, so that the same machinery serves a double purpose, that of working the mill and drawing up vessels. In this manner they draw their vessels from the canal on one side of a mountain to the other. In Europe, the nurse of science and the arts, to which in a great measure must be referred the successful completion of all great works, artificial rivers has presented an everlasting monument. In the year 1666, Louis the Fourteenth gave directions for constructing a plan to connect the ocean with the Mediterranean by the canal of Languedoc. This was a bold undertaking if it be considered that all the details connected with it were to be created, every thing was new; Francis Riquel was the engineer, and he lived to complete it. This canal is upwards of 64 leagues in length, and is furnished with 104 locks. It runs through rocks in some places of 1,000 paces in extent, in others it passes valleys and bridges by means of aqueducts of vast height. It joins the river Garonne near Thoulouse and terminates in the lake Tau, which extends it to the Port of Cette. It was began by forming a large reservoir 4,000 paces in circumference and 24 deep, which was supplied by water issuing from the mountain Noire. In Germany and the Low Countries, canals form the principal means of communication between one place and another. The canal of Bruges runs to the sea at Ostend, and is extended to Ghent, Brussels, Antwerp, and many other places: it is in depth sufficient to allow of merchantmen coming to the warehouse of its owner. These canals pass into the very streets of the above-named towns; indeed, in all Flanders and Holland, in towns of any importance, the streets are

intersected

intersected by the canals. In the line of the canal the street is sufficiently wide to admit of two commodious roads on its sides, which are not unfrequently planted with double rows of trees. Canal navigation in England may almost be said to have been began by the late Duke of Bridgewater in the year 1759; since which time the internal commerce having increased with the developement of the industry of the people, canals have been cut, which has given it a ready transit to every populous part of the island. The engineer intrusted with the making of a canal, should be fully informed by the projectors of all they wish to accomplish; and if he be a person of integrity and skill, in him their confidence should be placed. The preliminaries to an undertaking of this nature, consists in forming a minute survey of every part of the country through which the line of the canal is proposed to pass; and this should be done in the first instance by the principal engineer: all the principal heights should be accurately noted and ascertained; memorandums should be taken of all objects within the districts through which it is intended to pass, rivulets and mill streams marked so as easily to be referred to; the breadths of the various summits or ranges of high and low land that are to be passed should be ascertained. When a survey is so far accomplished, a rough sketch or map should be prepared, laying down to a scale every principal object within the proposed line. This map will enable the projectors to see the various obstacles to be encountered in the work; and also the engineer to display his talent in surmounting them. When so much is accomplished, the adviseable height of the summit-level of the canal must be ascertained in order to find the number and fall required in the several locks necessary to be constructed on its line, the proposed summit level should be traced along the hills and ranges of high-land, to see how far it is practicable to reduce it to the required height by filling up the low land by the excavated earth, or by deep cutting or tunnelling. When the summit-level is finally determined on, and also the line of the proposed canal, all springs and rivulets which rise above or cross this line should be traced, and the quantity of water they discharge accurately gauged: this part of the work is of the very greatest importance, as it may be turned to considerable account in affording a supply of water to the line in its neighbourhood. Mr. Eytelwein, engineer to the King of Prussia, has shewn many important facts connected with this part of the subject, deduced from experience and mathematical investigation. Dr. Young has compiled them, and they have been given to the public through the medium of the Journals of the Royal Institution, or see Nicholson's Journal, vol. 3. p. 25. In setting out the canal a good spirit level with telescopic sights is required for tracing the levels, and when traced they are marked particularly by what is termed a Bench-mark, which is no more than stakes driven into the ground at usually of the distance of every two or three chains, with their tops exactly projecting above the earth so much as to ascertain the top-water level. After this line shall have been thus traced and the bench-marks fixed, it should be accurately revised, and all sudden bends in its course rectified, so as to produce an easy undulating curve; it would be desirable to get the line as straight as possible, but ranges of high-land, property of particular descriptions sometimes intervene which prevents it. In such cases, as in the former for instance, it is often found more desirable to bend the line than to have recourse to deep cutting or tunnelling: in the latter description may be included gentlemen's parks, gardens, &c., and as few canal acts protect the proprietors in violating such property, the line must vary its course so as to pass round them. The widths and depths of canals vary in reference to the boats intended to work in them; 30 feet is a good width at the summit level; and it is sometimes varied with us to as low as 18 feet. In Holland they make theirs from 50 to 70 feet, and sometimes more. The Bruges Canal is 80 feet wide and 16 feet deep. The slopes to the sides of canals is of considerable importance, and this consideration has given rise to many speculations, which have added very little to the stock of information already collected. Mr. Eytelwien has recommended that the breadth at the bottom should be two-thirds of the depth, and at the surface ten-thirds; the banks will then be in general capable of retaining their form. The area of such a section is twice the square of the depth, and the hydraulic mean depth two-thirds of the actual depth. See Nicholson's Journal, vol. 3, p. 33. The practice in our canals is to so apportion the side slopes that one foot in depth will give a horizontal base of one foot and a half. The depth of the water must be in some measure deduced from the nature of the soil to be cut through, and the draught of the boats to be employed on it. The average depth of our canals lays between 4 and 8 feet, and the banks are made one foot higher than the water is intended to stand in them. The fall given to a canal, in order to produce a stream or velocity in the water, varies with the local difficulties to be overcome; and since inland navigation is determined to a precise point or place, the navigator calculates little upon the velocity of the stream downwards, knowing if it were made great what he might save in going down it would be lost in returning. Four inches in a mile is conceived to be a good fall for a canal 18 feet upon the summit level, and 7 feet at bottom, and 4 feet deep: the velocity of the stream in such a canal is, according to Professor Robinson, 17 inches in a second at the surface, 14 in the middle, and 10 at the bottom: from such a deduction it will not be difficult to extend the calculation to canals of greater or less dimensions. This conclusion is, however, only true of a straight river flowing through an equable channel; and as our canals are seldom straight for a mile together, but vary their course as frequently as change of place presents new difficulties, it follows, that the banks of the canals will be more often in a curved direction than a straight one; and Mr. Eytelwein anticipating such a circumstance,

circumstance, remarks, "that the velocity is greater near the concave than the convex side; a circumstance probably occasioned by the centrifugal force accumulating the water on that side."

When a canal is accurately marked out, and the bench-marks *firmly* fixed, a circumstance which cannot be too much attended to, as cattle often knock them down while grazing in the fields in which they are placed, and idle people as often from mere wantonness; if it be found difficult to keep the bench-marks in their places, holes must be dug to supply their places, and the bench-marks put up as the excavating proceeds. When the works have arrived at this state, calculations should be made of stuff wanted, or to be spared, upon the line, in order to its being removed with as little labour as possible. The top-soil and turf removed, allows of the canal line being easily worked upon.

The ground-men, excavators, or navigators, as they are called, are in some districts also called hag-masters; to these people the digging is let, at per cubic yard, according to the nature of the soil to be excavated, and the distance it is to be removed. Their tools consist of (if in a clayey or loamy soil) a grafting tool, the handle of which is rather longer than usual, with a narrow blade of iron, forming the segment of a circle, with its concave side turned inwards, firmly riveted to the handle and very thin at the lower end; the size varies to the caprice of the workman: they are usually about 10 or 11 inches long, and 6 or 7 inches wide. In some soils, gravel for instance, the same kind of tool is called a shovel; its blade is ground away till its lower end approaches an apex, the diverging sides from which form the slant ones, and make nearly an equilateral triangle. They have also a scoop to throw water, pickaxes, and wheel-barrows. The latter differ materially from the common machine of that name: it is framed of oak, the two sides form the handles, and also diverge away and admit the wheel between their opposite ends. Into the sides, two stout feet are framed and cross braced: the whole is fixed together by stout bearers mortised into the sides. The bottom is lined commonly with inch elm boarding, and the sides slant all round, and are about 6 inches deep. The wheel is usually of cast iron, very light, and its edge not more than an inch in thickness. The beauty of the barrow consists in its lightness, and should not exceed 40lbs. in weight, including the wheel. The labourer wheels the soil away in his barrow by a kind of tram-road made of planks, these being easily adjusted to all required positions.

Among the first works to be excavated should be the foundations for all locks, basons, and bridges, also the culverts and drains which are to pass under the canal. The work should be commenced as early in the spring of the year as possible, in which case many parts may be accomplished in sufficient time to allow of its settling and getting firm and dry before the winter season arrives, which, if severe, may delay its progress, and destroy such as may have been too recently set about.

The soils, through which the different lines of the canal is intended to pass, should be pierced and proved to ascertain their nature, and if good water-tight stuff, its extent traced, for on this must be determined where, and in what quantity, puddling may be required for the banks; for to prevent leakage in a canal, is that in which the engineer will display his greatest sagacity. Porous soils, or soils requiring puddle lining, consist of gravel, sand, loose or open rock, or other earths that will let water easily through; or earths in which rats or moles take up their habitation, or such as is much perforated by worms.

Some engineers have made use of strong clay for puddling, but it has been seldom found to answer the purpose, particularly to side linings; in lining the bottoms of canals it has a better chance of succeeding. It holds so much water, that exposure to the air evaporates it, and consequently it cracks, which renders it unfit for a safe and water-proof coating, which in some canals are particularly required. The best puddle is made of a light loam, and sharp siliceous particles or sand, in the proportion of two of the former to one of the latter: it is manufactured commonly contiguous to the slope which it is intended to line, but if the bottom of the canal should require lining also, it will be necessary to so dig the puddle-ditch, or gutter, as it is called, that it may be at least three feet below the bottom of the intended canal. When the ditch is ready to receive the compost of which the puddle is to be made, the loam and sand, in the proportions above stated, should be brought and thrown into the ditch, till its bottom is covered to about 12 or 13 inches in depth; it is then to be well covered with water, and it may stand so covered a day or two, if no particular hurry be required in facilitating the work. If expedition be required, the puddle-maker may commence his work immediately. The workmen are generally provided with a good and strong pair of water-proof boots; so equipped, they stand in the puddle-ditch. They are also supplied with a wooden chopper, or beater: the chopper is usually made of oak, with a rounded handle, and at its opposite end is the chopper, which is nothing more than a shaft worked away to an arris, and flat on its upper edge; with such an instrument they keep cutting and breaking the compost, at the same time treading it with their feet, till they get the whole completely incorporated and reduced to a tough and firm mass, and almost to a semi-fluid state all through the ditch, and when so reduced, it is left to precipitate itself, which is effected in 3 or 4 days: and if, after having stood so long, it is found to have become settled and firm, not to give way by treading on it, it is deemed in a state to receive a second coat. When this is put into the trench, and the water let in to it, the workmen should endeavour, in breaking it up, to strike their beaters quite through it, till they enter a small way into the coat previously prepared; in the same way a third coat is to be added, till the trench becomes full, and sufficiently high to reach the top-water or summit-level of the canal, or even a few inches more. When the puddling is so far advanced, the banks of the canal

canal should be firmly made up, and the towing-path formed to the proposed width intended, the puddle should be covered by sods, and left for use; after which the banks of the puddle-ditch may be cleared away, and the lining of the sides commenced. Their slope having been previously determined on, three feet is generally left to be supplied by the puddle lining. In cutting down the slope, all extraneous matter should be carefully taken away, such as roots of trees and plants; all vermin holes should be well stopped and secured, and indeed every thing which is thought at all likely to disturb the coating about to be added; and when ready, it should be worked down quite straight by the excavator's spade, and rendered tight and sound. After so much is done, the lining may be proceeded in, which consists in spreading on a coat of the puddle, varying from 7 to 12 inches in thickness, all through the canal line, which is ready to receive it; and when this coat is properly laid, and to the satisfaction of the resident overseer, it should be sprinkled with water, and remain till the following day, when a second coat should be added, and so on, till the coating has assumed the necessary and required thickness; and when done, it should be neatly smoothed down, and the water may be let into the canal.

It cannot be too much impressed upon all those who may be concerned in canal works, the necessity of particularly attending to the puddle-lining. Leakage in a canal is attended with so many embarrassing consequences; among them, loss of water is not the least, dilapidations of the embankments, and perhaps their being wholly carried away; for when percolation takes place, and that through made or artificial ground, its solidity is of very short duration. Nevertheless, it is but too often carelessly done; and this circumstance has led to an enormously extra expense, besides disgust in the contiguous land-owners, who have found their grounds constantly inundated by the leakage in the canal passing contiguously to them.

A canal is said to be performed by level cutting when the natural state of lands through which it has to pass are tolerably level, and approaching to a good summit-level to the next locks, both above and below it; when a line is to be cut through such grounds, nature is said to favour the undertaking, and it is, perhaps, truly said, for in Flanders and Holland the canals require no other consideration than in performing them in this way, and in them few locks are required, as a good summit-level may be accomplished by embankments, which are there called dikes. These, in countries like Holland, are of great consequence, and are commonly made wide and handsome, planted with rows of trees on their sides, and sometimes even paved; they are, in fact, the high roads of communication between one part of the country and another, and afford to the public the greatest accommodation, in giving them a dry and commodious road throughout the year, which could not otherwise be easily obtained in such swampy lands, which are more than half the year overflown by the swelling of the Rhine, and the consequent increase of water in the canals.

The Dutch have the credit of having invented the compost, or puddling: it is true, their canals are all so done, and indeed without it, in canals such as theirs, it would be totally impracticable to prevent their leaking. Their embankments, or dikes, are sometimes raised 12 feet, or higher, above the neighbouring land, and the top-water level reaches within two feet of the top of the dike. The difficulty of keeping in the water, in such high embankments, must be great, where nothing but earth is applied for the purpose; but the Dutch puddle appears to make a complete barrier. The writer of this article has examined the principal dikes in Holland and the Low Countries, and he invariably found they were coated with puddle, and in a similar manner to the way described above for weak or infirm embankments, except, perhaps, that they are more neatly done than with us, and they use a kind of marly clay in the compost, which is often rejected by our engineers. Indeed, canal making, in Holland, is a system interwoven with the nature of the country. It would be a complete swamp if it were not for the canals: they perform the double purpose of facilitating inland navigation, and draining the country.

Plate I. *Fig.* 1, is the section of a canal, shewing it under circumstances of level cutting. AA the line of the contiguous ground, BB the artificial embankments, CC the width of the cut at top, and DD at bottom. The external slopes can be so formed as to be used for the towing paths. With respect to the slopes CD, they are determined upon the principles already stated as prevailing among our best engineers for that purpose, viz. for every foot in depth, giving an horizontal base of one and a half foot; and it follows from such received data, that a canal 6 feet deep will require its sides to be sloped 3 feet, and if it should be 18 feet wide at the top water level, it would be 15 feet at the bottom: hence may be deduced very useful proportions for canals of greater dimensions, in which may be combined the practice found of utility in the smaller ones.

Canals are cut through so many variations in the ground's surface, that it would be impossible to anticipate them all: it is intended here, however, to notice two other cuttings, which will, in some measure, allow of great extension of application. When the ground slopes down to the projected canal line, it is called side-lying, and if a canal be forming through such ground, the work is said to be doing in side-lying ground. *Plate* I. *Fig.* 2, shews the section of a canal for such cutting. AA the sloping line of the ground; BB the embankments to be raised; CC the width of the cut at top, and DD the width at bottom. It is of some importance to so arrange the cutting, that the ground excavated from the canal be equal to make up the embankments on its sides: it is impossible that it should be so in all cases, but a great expense may be saved, if a calculation be made of it previously to setting out the summit-level of the work, as then the removal of the soil may be wheeled to the parts where it is most required, which will prevent heaps collecting about

about the works, which generates slovenliness, and sometimes the greatest inconvenience. Deep cutting arises when the canal approaches a hill, or the side of one which it is intended to pass by deep or open cutting, rather than by tunnelling. *Plate* I. *Fig.* 3, represents the section of a canal by deep cutting; AA, the inclined ground to be passed, CC, width of canal at top, and DD the width at bottom: the sets-off II, are generally appropriated in such cuttings for the towing paths, and are called by the navigators berms. They are also found to be exceedingly useful as a provision to prevent the loose ground which rolls down from the upper banks B and C from falling into the canal. It is in cutting in such situations that the ability of the engineer displays itself; he has often to contend with all the difficulties of a bad stratification, in which, frequently, the percolating waters become so great as to stop the proceedings. In such cases, pumps are had recourse to; but it sometimes happens, nevertheless, that he has no place in which he can convey the superfluous water, or if he has, he is not sure that it will not increase his difficulties, rather than remove them. To offer expedients for such circumstances is impossible; they must be met by the experience and resources of mind of him to whom the work is confided, and it will be well or ill performed, in proportion as his experience and talent predominate.

Canals of great traffic must be furnished occasionally in their course with passing places. They consist in giving an increase of breadth to the water way of the canal, so as to admit of boats resting by the way, without incommoding the navigation; every canal has them, and the only precautions are, that they be made in as convenient places as can be, to promote the convenience of the traffic; hollow and low places are generally selected as the most eligible, and near to the locks and basons if possible. By such places being formed, the public derive accommodation, as it admits of a ready transit of produce and industry to the inhabitants in its neighbourhood.

Reservoirs to canals, in most cases, are indispensable, in order to the keeping up a supply of water in its line; they are artificial collections, getting their water from every source in their neighbourhood; their size must be regulated by the quantity of water they are intended to contain, and that by the line of work which it may be intended to supply. They should be placed in situations so as to contain an equable quantity throughout the year, and so contiguous to the canal, as to admit of an easy communication with it at all times. Wherever the reservoir is to be constructed, all the variations of the ground's surface should be exactly noted down; the nature of the soil proved, in order to ascertain, if bad and porous, where, and in what quantity, lining or puddling may be required for it. The water flowing through all springs, brooks, and rivulets, which it is determined to divert, to supply the reservoir, should be exactly gauged, and also the depth of the rains which usually fall. All such particulars being ascertained, the excavation may be commenced; the same process is to be followed as has been recommended for the same kind of work in canals. The sloping of the banks is made rather more oblique than is practised for canals, commonly to every foot in depth an horizontal base of two feet, and if the excavation be in a strong clay, the horizontal base is made as much as three feet. The lining is performed in a similar manner to the way pointed out for such work in canals. Every reservoir should be furnished with a gauge, indicating exactly the quantity of water that it can supply, &c.; if the gauge be a wooden post fixed in the reservoir, it might be accurately divided, so as to shew, by its divisions, the water lost by evaporation, or taken for the canal; and this gauge would exhibit at once how the supply kept pace with the consumption. In the event of an excess of water flowing into the reservoir, which circumstance should always be anticipated in its construction, many plans have been suggested for disposing of it; the most usual way, however, of providing for a ready exit to such excess, is to form a weir or weirs, sometimes called tumbling bays, frequently at the corners, if the form of the reservoir be square; if round, or a compound figure, at such places as is best adapted to its ready discharge. It will appear quite obvious, that the size and number of the tumbling bays must be regulated by the estimated quantity of water they may be called upon to discharge, or the greatest inconvenience may follow; as in the event of their being too small or too few in number, in great swells of the springs arising from unusual rains, &c., the sides of the reservoirs may be overflown, to the destruction of its banks, and perhaps to the effect of blowing up and carrying away the canal works in its neighbourhood. The construction of a tumbling bay consists in forming a vertical syphon in the embankment of the reservoir, composed of well-wrought masonry or brick, properly cemented, to which an horizontal communication is opened by the side of the embankment of the reservoir. The whole workmanship should be done in the most complete and perfect manner; the bottom of the syphon should enter a culvert constructed in a similar way, which culvert or drain should be arched above and below, and be built upon an easy descent, so as to promote an easy discharge of its contents. The culverts are frequently carried under the bottom of the reservoir, in which case it will be essential to keep them sufficiently low to admit of the lining being thick enough to secure its water-tight qualities. In cases in which rivulets or other streams are diverted to the supply of the reservoir, a somewhat different construction will be required, than when it is fed by springs; this difference principally consists in an alteration of the approach by which the water is to enter; such water is previously collected into a branch, or, as it is termed, a feeder, which is in fact a canal of smaller dimensions than the principal one. This feeder is constructed so as to promote a current in its waters to the head of the reservoir, which it enters by a weir or gates, the sides or piers of which should be formed of masonry, built on a piled foundation,

foundation, in carrying up the work, which should be of large stones well joined, and the walls battering back from the line of their base, and somewhat curved in their whole height. The tops should be coped with broad slabs of granite or free-stone, dovetailed together, or well cramped. The bottom of the weir should be formed by an inverted arch of masonry, well bedded in strong clay or puddle compost. The gates should be made of strong oak, with lower and upper cills, framed with rails and cross braces, fixed in the stone sides by bars of iron. An iron upper rail should traverse the top side of the whole. The gate or weir should be in height a few inches above the summit-level of the reservoir, that the water from the feeder may flow over the bar of iron attached to the upper cill. The reservoir supplies the canal by means of a pipe of cast iron, or other metal, or stone. This pipe is furnished with a cock which works on an endless screw, and is so adjusted as to be easily turned by the overseer of the reservoir.

Mr. Longbottom obtained a patent for the construction of reservoirs (see Repertory, vol. 4, p. 145), the only novelty in which was, he depended for a supply of water to the rains falling upon the earth's surface, which he proposes to collect together into one or more reservoirs; the words of the patent run thus: "My intention is calculated to supply canals, ponds, sluices, towns, or any other place wanting water, by making reservoirs upon high and moorish ground, or any other suitable place which are to be supplied in manner following." He adds farther, that "he found that in twelve months there falls upon a superficial foot of land 3. 33 cubical feet of rain-water, exclusive of exhalation, so that upon a statute acre there falls to the amount of 145,054. 80, or thereabouts;" again, he says, "I can convey water falling upon 3,500 acres into reservoirs:" for instance, "I make a reservoir of 100 statute acres in the most eligible situation, from which open drains, or sluices, are made in the most proper places for receiving water running from the surface of the grounds in rainy weather, which, according to calculation, will be nearly equal to 5,076 cubit feet per acre, or 91,800 cubic feet per annum, brought into the reservoir, except in loss by soakage; this may be done without any prejudice to rivers or mills. The area of a reservoir of 100 statute acres is 4,356,000 superficial feet, and the average depth 9. 75; the parts are not included, so that 4,356,000, the area by 9, gives 39,204,000, as contained in the reservoir of reserved water." For conducting such water into the canal or sluice, he says, "I make two aqueducts of stone or brick for conveying the water out of the reservoir, from the bottom when the water falls perpendicular from its surface into the space of a large circle of stone work, with which the openings of the aqueducts communicate; in each of these I fix a paddle or clough equal to an opening of 15 inches by 12 inches, which is raised by a screw fixed to it, and moving upright in a piece of iron fixed across at the upper part of it: upon it is a square box including a female screw, in which the other moves, which is turned round by four small hand levers fixed to the square box, and which rests upon a small iron bar, which raises the screw and also the paddle, to the following heights, viz.: with an opening of 3 inches by 12 inches may be delivered 317,952 cubic feet of water in 24 hours; with one of 6 inches by 12 inches, 630,730 feet; with one 9 inches by 12 inches, 927,936 feet; with one 12 inches by 12 inches, 1,222,560 feet; and one 12 inches by 15 inches, 1,512,000 feet, or a less, or a greater quantity, in proportion to the opening and velocity. The quantity of water required to be let out of the reservoir may be regularly ascertained, by fixing at the head of the screw a pointer, and an index above it accurately divided into inches and parts; and as the paddle is raised by the screw fixed to it, the pointer at the end sliding upon the index will shew the quantity of water discharged upon every division of it as set forth; as at 3 inches in height, 317,952; at 6 inches, 630,730; at 9 inches, 927,936; and so in proportion to all the several proposed elevations." This specification concludes with directions for forming smaller reservoirs, in which many ingenious suggestions are developed. The reservoirs here treated of have been considered as formed by embankments, which, in porous soils, have been recommended to be lined with puddling: in some, however, such embankments will not answer the purpose, in such cases the whole must be walled with brick or masonry; and if of the former, the greatest care should be taken that they be well laid, and of great substance, with puddle linings behind them; the cement should be of fresh stone lime (and if ground instead of slaked with water the better,) mixed with sharp sand, and the mortar prepared for use only as wanted. The walls should batter back in their height with a small curvature outside, diminishing in thickness as they ascend, and finish finally at the top to two bricks and a half.—The whole should be coped with granite, with the meetings fastened by dovetails. If it be determined to form the walls in masonry, which, in some situations, may be eligible from the abundance of stone at hand, the same plan in the form of the wall should be had recourse to; and also, in previously lining the embankments, the ashlerings should be in as large pieces as may be conveniently obtained, and all venty or bad stones rejected.—The joinings should be as close as possible, with very little cement between them: the whole should be coped, as is directed before, for walls of bricks. Most of our canals are supplied by reservoirs somewhere in their course, so that an engineer can scarcely anticipate a work of canal making without feeling that he may be called upon to exert his talents to the forming of a reservoir. The principal reservoirs that have been already formed to canals are, one at Ripley for the Cromford Canal; another at Milstone for the Grand Junction; also, at Ainsworth for the Nottingham; at Marsden for the Huddersfield; at Littleborough on the Leicestershire Canal. The

Rudyerd

Rudyerd Vale supplies the branch of the Caldon and Mersey, and occupies upwards of 150 acres, and is more than 30 feet high. The St. Ferriol reservoir to the canal of Languedoc occupies a space of 590 acres: the walls of which are covered by ashlerings of freestone.

Locks, or pound locks, in the consideration of which many important circumstances develope themselves in the work of a canal, are the barriers by which the water is kept to its summit-level; in the several reaches on its line, they also operate as toll bars for collecting the tolls payable on navigating it: they are placed as frequently on the line of the canal as the several levels require them, and make a kind of step in the line throughout its course. They have been the great desideratum in canal-making among the moderns, as by the making of which, waters have been pent up in the reaches between them, supplying the means of navigation through high and low lands, from one part of the kingdom to another. In setting out a lock, care ought to be taken to get their falls as equal as possible, and this can only be done by the previous care taken in adjusting the summit-level of the canal. The lock comprises of itself a chamber and two pair of gates; the former is made of length and width adequate to admit one or more boats at a time either in ascending or descending the canal; this is effected by letting the water out of the chamber; if it be ascending, by opening the lower gates: but it is not usual to keep the lower gates of a lock shut, so that a boat or boats coming up the canal can be immediately towed into the lock, which, when in this state, is said to be empty, although it contains as much water at least as is in the lower reach of the canal; when boats have thus entered the lock, the lower gates are loosened, and the paddles of the upper gates are gradually raised, which admit the water to rush into the chamber of the lock: the velocity of the stream soon closes completely the lower doors; and when they are shut, the upper gates are regularly opened till the water has completely filled the lock, which it does in a very short time, and becomes at rest between the lower gates and the upper reach of the canal. The tolls being paid to the overseer of the locks, the boats are towed out, and if no others are waiting to descend the canal, the lower gates are opened and the upper ones are again closed, when the lock empties itself and regains its former state. It will be perceived, that the upper line of the canal will lose its waters in proportion to the working of the locks, hence it becomes desirable to make them as small as possible; and it is also of importance that they should be of the same size throughout the line of the canal, that the loss at each lock may be equal, in which case the supply to be anticipated may be correctly ascertained. In the approaches to all locks, both above and below them, there should be made resting places, provided with oaken piles driven down close to the embankments, which they may be made to support, with their upper ends crossed by strong whaling boards of oak, bolted with iron bolts to the heads of the piles. If the whaling boards have large iron rings fixed in them, the bargemen will have the advantage of fastening their barge to them during the time they may have to wait for passing the lock. Twenty-five-ton boats, according to Mr. Fulton, consume in ascending a lock of 8 feet rise, 163 tons of water, and in descending the same, 103 tons; now, if such a data be correct, it would enable an engineer to make very accurate calculations of the loss in water in all his several locks upon the proposed line of the canal: that more water should be lost by ascending a lock than in descending, appears probable, although the same space requires filling in both cases; but it does not appear so obvious, how so great a difference as 60 tons can take place; but this could be settled by a reference to the draft of the boat employed, knowing that it displaces as much water as its cubical contents, if it be laden adequately: these are all investigations pressing on the consideration of the engineer. *Plate* 1, *Fig.* 4, is the ground plan of a lock, A, A, A, A; strong piers of masonry or brickwork bonded into the wing walls, F, F, F, F; B the chamber of the lock; C C the gates; D D the side walls of the chamber; E E the vertical syphons to take off the superfluous water from the head of the lock. The building of a lock requires the utmost attention in all its constructive parts; when the form is traced out, and the top soil removed, the ground should be proved to ascertain its nature, and if soft and porous the foundations should be piled all through, the tops of the piling should be regularly sawn down and planked with oak of not less than 3 inches in thickness, which planking will form the platform on which the walls are to stand: in forming the foundation wall, some attention must be had to the inverted arch, which composes the flooring of the chamber of the lock. *See Section, Plate* 1, *Fig.* 5. The inverted arch, K, should be formed of hewn stone of small curvature; its thickness in the centre about two-thirds of that of its spring; the joints of the voissoirs are also all traced from the centre of curvature of the arch, and also the springing line; the bottom of the arch should lay upon a good lining of puddle, and the joints of the stones should be well cemented so as to be water-tight; the abutments, or bottom of the side-walls of the chamber, should be of twice the thickness to what they are above, and should rack-back in ascending; linings of puddle will be judiciously employed in covering the earth of the embankment behind the chamber walls. Lock walls are usually parallel to each other, and the lock varying in width from 14 to 18 feet, and in length from 70 to 90 feet. The plan, (*Plate* 1, *Fig.* 4,) is conformable to this proportion: the side walls of the chamber batter back as they approach the coping at their tops, about 6 inches from their perpendicular; and if they were made to have a slight curvature in their height, they would be much stronger for it. In building the piers, as shewn in the plan at A, it is necessary to observe, that they should be out of large blocks neatly worked and hollowed out to admit of the gates working in them. The wing

wing walls should be raised in a similar way to the walls of the lock, except that no provision is required in them to receive an inverted arch, as the approach or breast of the lock requires no such protection. Apertures should be made through the side walls of the wings to admit of the superfluous water entering the culvert through the syphon, as seen in the plan at E, and in the section by the dotted lines; and if the culvert be bent in its course, this water, if it be required, may be made to enter the chamber of the lock, a circumstance of some importance when there is a scarcity of water. When the lock is so far formed, and its syphons and culverts made, the lock cills should be put down; they consist in forcing into the ground at the two ends of the bottom of the chamber of the lock, a row of narrow piles extending from one side to the other: they should be driven as close together as possible, and when so driven, they will form a chain across the two ends of the lock: in this state their tops should be sawn off quite level and smooth, and a sheeting, as it is called, of good oak or cast iron should be bolted on them with iron bolts, to form the lock cill for the gates to move upon, and also to protect the approaches to the lock. In the wing walls there should be inserted in their progress some large blocks of stone, projecting somewhat from the face of the ashlering of the wall, and called bumping stones for the boats to strike against as they enter the approaches to the lock. The lock walls and those of the wings should be coped with granite, firmly fixed and cramped. The gates C C are made in two parts, and form at their meeting an obtuse angle; they move in the hollow quoin stones, and by means of iron joggles fitted into sockets, which should be let into the hollow quoin stones of the piers A. *Plate* 1, *Fig*. 5, is the section of the lock; G G the granite coping; H H the top of the sloping side walls; I I the base of the sloping wall; K the inverted arch at the bottom of the lock; L L the syphons of masonry or cast-iron, worked up in the wing walls at the head of the lock to carry off the overflowing water; M M the culvert or drain; N a cesspool to receive any matter carried by the water through the culvert, to prevent its overflowing or stopping up; O O the horizontal apertures in the wing walls communicating with the syphons L L. These apertures should be made a few inches below the top-water level, and if formed in stone composed of a large block perforated quite through, and the size of the opening regulated by the quantity of water to be discharged, but they might be formed of cast iron with the best success. It will be unnecessary to add, that all the work of a lock requires the materials and workmanship of the very best quality, and the engineer will more develope his constructive talent in adjusting its form and the mode of putting the materials of which it is to be formed together, than he can in any other of the arrangements arising out of the works connected with canal construction. *Plate* 1, *Fig*. 6, is a pair of lock gates: they are shewn to a larger scale than the plan or section of the lock which accompanies them, in order to exhibit the mode of their framing more obviously. They should be made of good seasoned oak, free from vents or sap, and are composed of several pieces known by the following designations: P P the balance beams, Q Q Q Q the rails, R R R R the vertical styles, S S S S the braces, T T the paddle holes, and they are finally covered by oak planking grooved into the bottom rail and the balance beam at top, the joints of which are also rebated, or grooved and tongued. In some lock gates the boarding is fitted in diagonally, in which case the braces may be dispensed with; but greater strength can be accomplished by framing them as shewn in *Fig*. 6, and there will be also a saving of wood. The scantling of the timber in the lock gates may be varied to meet the pressure they may have to sustain, but it will be indiscreet to attempt making them too light. The rails Q Q Q Q should not be less for ordinary purposes than 10 inches in depth and six and a half inches in thickness, and this would be a very good scantling for the stiles R R R R; and supposing the planking to be two inches and a half, the cross braces S S S S would be properly proportioned to be left seven inches on the face by four inches in thickness. The balance beam, which also forms the top rail of the gates may be made somewhat larger in scantling than the lower framing, and the stiles might be framed into it. If this beam was made at its smallest end eight inches square, and at its opposite end ten inches and a half, it would act as a good balance to the gates, and give to them great strength. The boarding should be flush on the upper side, and well spiked to the middle rail and also the braces. The projecting edges on the inside of the gates of the rails and braces should be splayed downwards in order to the water running quickly off them, and the balance beam should be weathered on its top edge. The iron work to the gates consists merely of its hinges, the socket of which are previously inserted in the stone quoins of the wing walls. In fixing the iron work it should be made to lap quite over the outside stiles and be bolted with iron bolts, with nuts, and screws. Sometimes the bottom of the gates are shod by plates of cast iron, and these plates are also continued up the centre stiles, and it must add great additional strength to the framing. Some have recommended the giving to the external form of lock gates a small degree of curvature, supposing, no doubt, that by such curvature they would give additional strength to the gates; but the momentum of form would be more than surpassed by the loss of strength in the materials, as by cutting wood purposely circular so crosses its grain as to leave it with very little strength at its joining, besides a double expense in the actual cost of the gates themselves. It has been deemed proper to notice this circumstance to prevent theoretical engineers from disappointing themselves in the application of curvatures to wooden framings in which strength is sought; for it will lose strength by such curvature in a ratio of greater proportion than it can possibly gain it, which will be easily discovered

discovered by an inspection of the state of the fibre in circular wood framing.

The paddle holes T T are small openings left in each gate, generally about twenty inches square, and to which a small door is fitted; they are found of the greatest utility in preventing a too sudden swell in filling the chamber of the lock, and also in removing a portion of the pressure of the water from the gates when they are required to be opened in letting a boat descend the canal. They are so adjusted to the boarding of the gates that they can be easily raised or lowered by the overseer of the locks. This is done by supplying a guard bar to the top of the gate, which is operated upon by a rack and pinion, that has the effect of lowering or raising the paddle doors at pleasure. Amidst the considerations arising out of the detail of a lock, it will be eligible to notice that in long lines, and on which there is great traffic, sometimes there arises too great a scarcity of water to supply the upper reaches, in consequence of which many expedients have been recommended, and some have been had recourse to, to avoid the inconvenience. On the Grand Junction Canal, reservoirs have been made to collect the waste water of the lockage, to which a steam engine has been erected, which pumps the water after having emptied itself into the reservoir, back again into that part of the canal from which it has been lost. And there has been also another expedient recommended to remove the same inconvenience, under the designation of side ponds. A side pond or ponds consist in forming on the right and left of the chamber of the lock a number of projecting cisterns, varied gradually in their elevation, beginning a small distance from the bottom at the lower end of the lock, and stepping up to the upper end or head of the lock, provided with paddle doors. These cisterns, in capacity, are made so as to contain all the water, or nearly so, that passes the upper gates on a boat or boats ascending or descending the lock. When the chamber of the lock is full the highest paddle doors are opened, and the water empties itself into the cisterns right and left, and so on till all the cisterns are full, observing to shut the doors of the cisterns as the water retires in the lock; and this is done till the chamber of the lock is so emptied as to allow of its lower gates being opened. When the boat ascends or descends the canal, it will be seen by this plan that very little waste or consumption of water by lockage can accrue, except that which must necessarily be so by allowing a sufficient quantity in the bottom of the lock to keep the boat afloat and level with the lower level of the water of the canal. Mr. Playfair, an architect who gave rise to this invention, obtained a patent for it in July 1791; the specification of which may be seen in the Repertory, vol. 3. p. 303. In the patent the application is supposed to be employed under the following circumstances, for example: "a lock is supposed to be constructed twelve feet deep, sixty feet long, and six feet wide," and it is calculated that the quantity of water required to fill such a lock to enable it to pass a boat is 4,320 cubic feet, and in ascertaining what water may be necessary for supplying the canal, allowing for waste by evaporation and soakage, it is found (according to the number of boats that may be expected to pass) that there will not be above 800 cubic feet for each; and hence, it is added, it will be necessary to save five-sixths of the whole; to do which ten cisterns are directed to be made, each of which must be one foot deep, and each have a surface of 360 feet superficial. The aperture or entrance to the lowest cistern must be one foot above the level of the water in the lower part of the canal, and eleven feet under the level of the high water; the second cistern two feet above the level of low water, and the third three feet, and so on.

It has been deemed desirable to quote so much of Mr. Playfair's specification to illustrate the application of side ponds, and it cannot fail of producing a conviction of their great utility to canal locks, whenever there is reason to anticipate a want of water, as generally the greatest source of its loss is by the lockage. By the application of side ponds, this inconvenience may be in a great measure superceded, and at no great additional expense to the works.

Basons.—These are formed in all towns to which the canal has a communication, in order to make a commodious place for the boats to unload their cargoes and to take in fresh ones. Their size varies according to the importance of the town, or to the trade carried on at it. Surrounding the basons, a spacious area of ground should be gotten to admit of warehouses, cranes, toll-houses, and other stowage for goods, being built, with adequate space for all the vehicles employed in the trade to receive a ready transit and exit in their business about the bason. Convenient approaches should be formed to the wharfs for carts, and also roads with the shortest and readiest way of their departing when laden or unladen. The toll-house should be placed near the principal entrance to the bason, and should consist of two or more rooms for the keeper, with an office and weighing bridge. In the office should be written in legible characters the different tonnage and other charges to be collected, by the keeper, of the persons who trade on or about the bason of the canal. The construction of a bason consists in forming a chamber or head, sufficiently capacious to admit of boats resting in it, with room to unload and retire. The size, as before observed, must be commensurate to the number of boats expected at the bason. The embankments should be quite level with the wharfs, on contiguous ground, and about one foot higher than top water level. The termination of the bason is generally made to form a bow or semi-circle on the plan. All the embankments are faced by walls of masonry or brick, and the tops should be coped with large blocks of granite. In raising the facings to a bason, the same precautions should be had recourse to which have been previously recommended in the construction of the chamber of a lock; for instance, if a soft and porous soil, piling must be employed in the foundations, with a covering of oaken plank, and the earth embankment must be covered with a puddle lining previously to

raising the walls of the facing. The walls should be of great thickness at the bottom, racking back on their outsides and battering over on their insides; and their slope will require to be in proportion and parallel to the canal embankment, in order to the general surface of the lines approximating together. In carrying up the facing walls, nevertheless, a few niches of curvature to produce a swell internally in their height would add greatly to their strength in resisting pressure. A bason must also be provided with a weir, syphon, or waste gate, in order to discharge the water constantly flowing into it from the upper reaches of the canal by waste of lockage, &c. If it be determined to discharge this water by a weir or syphon, (perhaps more than one may be necessary), culverts should be made to receive the water and discharge it at the most convenient places; these culverts require executing in the most substantial manner to prevent their blowing up by the weight of water they may be called on to discharge. They should have also some cess-pools in their course to receive any solid or other matter floated into them through the weir or syphon. Some basons are released from overflowing by a waste gate; this is the case with the bason to the Oxford canal at Oxford. This bason is so near the river Isis as to admit of an easy communication with it; and availing itself of this circumstance, the bank between them has been pierced through, and the embankment at the piercing right and left has been faced by masonry, (*See Plate* 1. *Fig*. 7.) From the waste gate V V, the walls right and left are splayed off at the embankments of the canal approaching the bason, and turned circular at their opposite ends, a rebate is left in the masonry for the gates to hang in at W W. The tops of the walls are coped with strong freestone, and the gates X are of oak, but without paddles. Returning again to the bason, it will be necessary to observe that guard rails are found necessary to be fixed against their walls to prevent the boats from striking against them. The guard rails consist of a series of strong oaken piles driven down into the bed or bottom of the bason, slanting to the side of it at intervals of about ten feet; and on their facing near their tops are broad planks or rails of oak strongly bolted to them with iron bolts. These generally form a continued chain, traversing the whole facing or embankment of the bason. Iron rings are fixed into the rails or piles at convenient intervals, for the purpose of allowing the bargemen to lash their boats to, while taking out their cargoes. In some cases large stones are worked in the walls for this purpose, and called bumping stones, to which rings may be fixed for the lashing to of the boats.

It will be necessary in this place to notice the several contrivances had recourse to for supporting the water in a canal, against accidents to its embankments, and other unforeseen events arising out of the imperfection of the means employed for such purpose. Safety gates are among the expedients made use of in such a dilemma; they are a contrivance for stopping the water in a long line of a canal when there is danger of the embankments giving way. *Plate* 1. *Fig*. 8, sheweth the plan of a safety gate or gates, P P the walls of masonry or brickwork built in each opposite bank of the canal, R R R R piers of masonry to strengthen their extreme ends, E E small projections worked up to stop and hinge the gate to; K, sinkings in the wall to admit of the gate laying in flush with the wall; D, the safety-gate. The plan is shewn with two gates, one for the purpose of supporting the water in the upper, and one also for the lower reach of the canal; and these can be shut as required by the repairs to be done, whether up or down the canal. These gates move upon the same principles as lock-gates, and require a similar contrivance, excepting that they are commonly in a single gate only. The walls of the safety-gate should be built on piled foundations of adequate substance at bottom, racking back outside, and battering inside, with a slight curvature; they should also be coped at their tops. The gates should be of good sound oaken wood, and prepared in a similar manner to lock-gates. (See *Plate* I. *Fig*. 6.) Advantage is sometimes taken, for the purpose of economy, of forming the safety-gates in the pier walls about the bridges, if bridges of masonry happen in eligible places for the purpose. [illegible] of the greatest utility on a canal, and claim par[illegible] attention in arranging the most eligible site for their erection; and their mode of building should be of the most substantial kind. They are indispensable in long levels, to protract dilapidation, where the cuttings are much embanked.

There is also a contrivance of a similar nature called stop-gates, the construction of which does not differ materially from the safety-gate, except in its being made to lie flat at the bottom of the canal, instead of being balanced above, as is the case with safety-gates. The mode of raising the stop-gate is by a chain, which is fixed to the gate under water, and when it is required to be raised, the chain is used for that purpose. Stop-planks are also often employed on canals for stopping water; they are a very simple contrivance, and consist in previously working up walls in the two opposite banks, formed with a groove or chase, into which the stop-planks are forced, and pressed down to the bottom of the canal. These answer the purpose effectually on narrow canals. Stop-bars are another contrivance, similar in manner to stop-planks, the walls for which are grooved to receive the bar. These are used as toll-bars, at the toll-offices on the canal line, and are to be so contrived, as to be opened and shut by the overseers attending at the toll-houses. They may be esteemed the turnpike-gates of a canal.

Aqueducts are frequently employed on a [illegible] for the purpose of extending it over rivers, and between two opposite ridges of high land. For this latter purpose, they were often erected by the Romans, to convey water for their baths and fountains, as the ruins of many of which still in existence fully demonstrate; but the Roman aqueducts were never intended for any other purpose than to convey water for the people's use; hence they

they were confined in their dimensions, and were little more than long narrow walls, with a void through them as a passage for the water. The aqueduct at Chapanost near Lyons, is raised upon arches of masonry, on the tops of which is a narrow channel for the water, arched over at top, the size of which is 6 feet high and 3 feet wide, lined in the inside with a lining of strong cement about 6 inches in thickness, which is quite perfect even at this time. There is another at Montpelier, which passes the river De Baunon, and across the valley, of a similar construction. Louis le Grand ordered an aqueduct, which is built after the same manner, and which conveys the water to Versailles. They are also numerous in every part of Italy, and wherever else the Romans extended their power; but since the discovery of Galileo, which demonstrated the important effects of the weight and pressure of the atmosphere, aqueducts in the Roman manner have become useless; as his discoveries shewed that water would not only elevate itself to the syphon line, but might be raised to about 34 feet above that line, by the means only of the atmospheric pressure. *Plate* II. *Fig.* 1, is the plan of a design of an aqueduct bridge to cross a navigable river, supposed of 300 feet wide. AA the piers, BB the wing piers and walls, CCC the water way; the longitudinal dotted lines shew the course of the aqueduct in the superstructure. *Fig.* 2, is the elevation: It has been deemed eligible to shew a bridge of this description, with some reference to architectural design, which is too often neglected, when the expense would not be increased by attending to it, as whether a stone or brick is placed in one way or another, there can be no difference in its expense by such placing, but in this placing arises all the difference between the artist and the artisan. *Fig.* 3 is the cross section of the bridge; C the spring of the centre arch, shewing the splaying sides and its intrados: H the solid masonry above the springing line; DD the embankments and towing path to the aqueduct; EE the width of the water way at top, FF the width of the water way at bottom. The rounded parapets II are proposed to be raised above the towing path right and left, as a protection to the passengers moving on the sides of the aqueduct. The construction of an aqueduct bridge requires all the talents necessary to be displayed in the erecting of other bridges, with the additional skill of giving to the road way water-tight qualities. The piers of a bridge of this description should stand on piled foundations, in order to give them the greatest firmness, and the usual process of erecting pieces of masonry in water should be followed. Caissons, or water-tight boxes, should be made to raise the piers in, until they are built above the top water level; the abutment piers should be formed behind a coffer-dam, and the whole of these parts of the substructure should be raised to a similar height previously to raising the centering on which the arch is to be built. (For a particular description of the caisson, coffer-dam, and other details connected with bridge building, see the article Masonry.)

Stone is the eligible material for building aqueducts, inasmuch as a greater firmness will result to the parts, and without a firmness and equilibration in it, the aqueduct will be subject to leakage and dilapidation. The embankments at the two opposite ends or wings should turn somewhat outwards, to allow of more easy approach, as is common in most bridges. The sides or banks of the aqueduct, crossing the bridge, should be formed of solid masonry or brick-work, and of good substance, battered over as they approach their tops, and somewhat curved, which will add to their strength and solidity. The edges of the wall should be coped, and the banks or towing paths paved. The lining of the aqueduct should be conducted in a similar manner to puddling, excepting only it should not be common lining of that nature. Parker's cement makes an excellent lining, and is perfectly water-tight: this might be laid on the masonry to a consistence of about an inch in thickness, smoothly spread, to the face of which a coating of common puddling might be applied, which together would be a secure protection against leakage.

The multiplication of canals in every part of the country, with the experience arising out of it, has produced a new application to buildings for this purpose; for there has now been erected, to the Shrewsbury canal, an aqueduct composed almost wholly of cast-iron, and which may be considered as the first of the kind ever formed. In the Rev. Mr. Plymley's report of the agriculture of Shropshire, is the following account of it, in which he says: "The canal passes the valley of Tern at Long, for a distance of 62 yards, upon an aqueduct made of cast iron, excepting only the nuts and screws, which are of wrought iron; and I believe this to be the first aqueduct for the purposes of a navigable canal which has ever been composed of this metal. It has completely answered the intention, although it was foretold that the different degrees of heat and cold would be such as to cause expansion and contraction," from which it was concluded to be improper for this purpose. It is necessary only to observe, that the objections to iron were founded in fact, as all metals are more or less influenced in their form by different degrees of temperature; and it was extremely probable, in the situation of an aqueduct, which is exposed so much to the vicissitudes of heat, cold, and oxidation, that it might turn out to be improper for that purpose. Time can only be the test of the propriety of establishing aqueducts of cast iron. Nevertheless, there are several at this time erecting, but in some of these there is a greater combination of stone, and also of wood, than has been employed in the one at the valley of Tern. Mr. Fulton, in his treatise on canal navigation, proposes that the "buttments and piers should be raised of stone, after which it will be necessary to extend pieces of timber across the span, and each to be traced back and covered with planks, to form a stage or scaffolding: on this is fixed the iron-work of the aqueduct, which may be all cast in open sand, and of the following dimensions; for instance, the span 100 feet, and the versed sign of the arch 1-6th of the span; then three segments of a circle, each

each in three pieces, about 36 feet long, 8 inches by 4 inches diameter, and to be united; then three straight bars to extend from one pier to another, to be of the above diameter, may also be cast in three pieces, and which bars are to extend along the tops of the segments to the piers, and form a line parallel to the horizon. The bars and segments to be united by perpendicular stirrups, 10 or 15 feet distant from each other. The mortise in the lower end of the stirrup being 13 inches long, will be sufficient to secure the segment, and leave room for a hole two inches square, through which a cross brace is to pass and fasten the segment at proper distances. The brace to have a mortise cast on each side of the stirrup, in order to allow of tightening the work by wedges. The trough plates should be at least one inch thick; the side plates 6 feet wide, and as long as can conveniently be cast, which may be 12 feet, and perhaps more, the flange to be made outside of these plates. The bottom plates may be 6 feet wide and 13 feet long, and in order to support the horse path, two of these plates laid across the stage and screwed together, with a flange under them, will compose a length equal to one of the side plates. The whole may in this manner be screwed together on packings of wool and tar, and the seams pitched. On the plates composing one side of the trough, brackets about 3 feet from the top must be cast and fixed, in order to support the horse-path: perpendicular rails, 8 feet long, being raised from the arms of the bottom plates will support the outside of the horse-path. It is added, that by pursuing this method of forming an aqueduct of cast iron, very few patterns will be required; *two* will be sufficient for the trough-plates, and but few will be required for the springs, rails, and spurs."

Mr. Jessop is performing a most stupendous work of this kind on the Ellesmere canal, for crossing the Dee river, in which are employed 19 ponderous pillars of stone, at 52 feet distance from each other, the centre one of which is 126 feet high. On the tops of these pillars are supported a number of elliptical cast-iron ribs, which by means of uprights and horizontal bars, support an aqueduct of cast iron 329 yards long, 20 feet wide, and 6 feet deep, formed of massy sheets of cast iron cemented and rivetted together, having on its southern side an iron platform for the horse or towing path. (See article Canal, Rees's Cyclopedia.)

To conclude, it will be necessary to observe, that every aqueduct ought to be provided with stop-gates at the most convenient parts of its length, as well as syphons or other means to drain off the water if required, for repairs or accidents. The stop-gates will be necessary to effect this purpose, and provision should be made for their erection in the first beginning of the work. They are most usually placed at the approaches or wings of the aqueduct.

Tunnels, or subterraneous passages, are now become familiar, as a means of conveying canals through ridges of high ground and mountains; they are also formed as roads through hills and under the beds of great rivers, to keep up easy communications between parts otherwise inaccessible, except by routes circuitous, and of course tedious. Perforations for this purpose were not unknown to the ancients, for we find the Romans frequently making them in order to carry forward their aqueducts. For this purpose they were not required on a large scale, but although small, they gave rise to the practicability which to the ingenious was a sufficient stimulus to create the means of performing greater undertakings; and which has now been acquired and effected through the multiplied local impediments which have presented themselves to inland navigation. The first subterraneous canal or tunnel ever made for the navigation of boats, was at Beziers, on the Languedoc canal in France; and it is believed the first in England was at Worsley, by the late Duke of Bridgewater, but this was to establish a communication to his coal mines only. However, there are now almost as many tunnels as there are canals, and the business of making them is so well understood, that they are set about with as few preliminaries as the deep cutting of a canal.

Previously to beginning a tunnel, the hill through which it is to be formed should be bored in several parts, to ascertain the nature of the soil to be excavated. This being well ascertained, the needful tools and machinery can be collected, that the work may proceed without delays. In setting out a tunnel, it is necessary to observe, that it must be quite straight from one end to the other. In tracing the line of the tunnel over the surface of the high ground, a number of small round poles are made use of, their tops painted white, to give them a more obvious direction to the sight: these are set up firmly with braces, at about 150 yards apart, and called by the navigators, excavators, or miners' bench-marks. When the line of the tunnel is accurately traced out, another row of bench-marks should be fixed parallel and opposite to the first, at a small distance vertically from the greatest diameter of the tunnel. These bench-marks will be the places where the shafts or pits are to be sunk, for the purpose of assisting the excavators or miners, and also of allowing the soil to be raised through. In sinking the shafts, which should be at *least* 7 feet in diameter, and as deep perpendicularly as the lowermost line of the bottom of the tunnel, a kirb should be made of wood, consisting of two circular ribs, and placed 4 or 5 feet from each other, and boarded over. With this kirb the shafts can be sunk to any proposed depth, without danger of the ground giving way; and the steining of the sides of the shafts with brick-work may or may not be had recourse to, in proportion to the strength of the soil, which, if good, may be supported by braces and planks only. If the places of the shafts are all marked out at the time of the tracing of the tunnel line, and sunk a small distance into the surface of the hill, they will, in the event of the bench-marks being broken down, remain as guides to the excavator.

After the work has arrived so far, and every other needful arrangement made, in collecting machinery for removing

removing the soil, the work should be begun by cutting down the headings on each side of the hill intended to be perforated, which should be excavated, and the soil removed, to allow of getting quite up to the approaches of the tunnel. When the approaches are made, the form of the tunnel should be traced on the section of the hill, either by a mould or otherwise. The work having so far proceeded, the perforating is to commence; and this is done by opening a communication from the first or second shaft into the ground in the line of the tunnel, and working opposite to it right and left. Preparation should now be made at the top of the shaft for raising up the soil, and this is done in several ways, the most common of which is to station at the top four or more men, standing on a platform raised 3 or 4 feet from the ground; these men turn the handle which is at both ends of a roller, and to which a rope is fastened, with a square bucket or buckets appended to each end of it; they are so regulated in size, as that two can move in the shaft or pit at once: the men in working the roller, that is by turning it round, raise one bucket while another descends, and in this manner they keep raising the soil as fast as it is excavated. In some cases, a horse-gin or turn-beam is employed, similar to those used at coal mines. As the tunnelling proceeds, the upper ground should be well propped with planks, and every part secured; as the miners advance in the line, abundance of ribs also should be prepared to turn the arch of the tunnel upon, and moulds and trammels made for the inverted arch forming the bottom.

The section of a tunnel consists in forming an inverted arch at its bottom, composed of masonry or brick-work: this arch is generally the segment of a circle, and is laid on a good bed of puddling. On the two ends of this arch rise the soffit arch of the tunnel, which in figure is commonly a simple catenaria, a parabola, or ellipse, of sufficient elevation to admit of boats riding easily through it. *Plate* II. *Fig*. 4, is the section of a tunnel: A the inverted arch at bottom, BB the foundations of the soffit arch, DD. E the shaft or pit for taking up the soil excavated from the tunnel, FF, the guard-rails and chock-blocks fixed to the sides of the tunnel to keep off the boats. The dotted lines at C is the drain or sough to convey away the percolating waters. G the soil to be rammed in upon the soffit arch. *Plate* II. *Fig*. 5, is the plan of the inverted arch to a larger scale. This arch is commonly wrought with a trammel rod, which consists (if executed in brickwork) in setting up a vertical piece of wood, to which another piece is adjusted by a centre which allows of an easy motion right and left, and describes the figure of the segment by its motion. A is the trammel rod, B the vertical shaft to which it is fixed. The trammel can be shifted at pleasure, and is an easy contrivance for forming inverted arches. *Plate* II. *Fig*. 6, is the section of the soffit arch of a tunnel to a larger scale, shewing it with its centering. The beam A may be fixed upon the chock-blocks previously worked into the inverted arch, at F, *Fig*. 4. The queens DD may be notched into the back of the beam A, or mortised through it and wedged with sliding wedges. The strutts BB may be of one and half or two inch deal, bolted with nuts and screws to the ribs GG, and to the queens, DD. The same bolt which fastens the strutts to the ribs, may be made also to fasten the lap-joints in the ribs also; the straining beam O may be in two thicknesses put on to each side of the ribs and heads of the queens, with a shoulder to the latter, and one bolt in each will suffice to fasten the whole. The meeting of the centre or rib, at the apex E, should be lapped and bolted with a nut and screw. This may be braced if required. The void F will be found useful to the workmen, in allowing them an easy access into the tunnel to notice the state of the work, and also to see if any settlement is taking place in the centering, &c.: which if found weak, cross-braces may easily be fixed in it.

It is not common to make a horse-path in a tunnel, and this is one of the greatest inconveniences attending on boats passing through them, as the bargemen are obliged to scramble through as they can, by placing their hands against the walls, and pushing on their boat in any way. It would be perfectly easy to remove this inconvenience, by making the diameter of the tunnel somewhat larger, and working into the walls, one foot above the top water line, or if it were below that line it would not much signify, a number of iron brackets, projecting from the brick-work about three feet; on these brackets could be laid cast iron plates sufficiently strong to admit of horses passing over them. On the edge of this platform should be a small cast iron rail; or there could be uprights at all the brackets, with a perforation in their tops, to admit of a rope or chain passing through them, which would act as a guard-chain or rope to the horse-path. The tops of the iron plates might be covered with a strong soil and gravel for the horses to walk upon, and thus would be removed one of the greatest defects in the navigation of a tunnel.

The centering ribs should be made in three or more parts, and they should be so adjusted together, that on the parts approaching one another they should produce the required arch, when they may be fixed with nuts and screws, taking care that the meetings be tight and close. The lower or inverted arch being turned a small way, the ribs for the soffit arch may be placed, 3 or 4 of which will be enough at a time; and these are fixed on a piece of timber called a sleeper, which is fastened at the base of the pit, and upon the chock-blocks; as the ribs are raised and adjusted to their places, their upper edges must be covered with laths to support the bricks of the tunnel arch. When the first yard of the arch is turned, the ground above the brick-work of the part formed must be well rammed and filled up, till it is as sound and firm as possible, and this must afterwards be repeated all through the work. After this is done and finished, more ribs must be placed and lathed, and the arching again began. The workmen now look at their work with more firmness, as they see and comprehend it more completely: they begin now at each end of the already erected arch, one set of workmen working

working one way, and one set another, which they continue till another yard be done, which is filled up and rammed as before. It will be sometimes necessary to avoid the effects of the percolating waters, to make at intervals, or wherever it becomes troublesome, cross-drains or soughs running quite under the tunnel, into which an opening can be made for the water to empty itself, and which may be carried off, or turned into the lower reach of the canal.

After three or more yards of the tunnel be completed, the work should be left to settle and get firm; this will be effected in a week or two, according to the state of the weather and the nature of the soil in which the tunnel has been made. If the above circumstances be at all favourable, a week will be sufficient; the nuts and screws may then be taken out of the ribs, and the first part of the tunnel centering taken down to be fixed in another part, and this may be continued all through the work, which will produce a great saving in ribs, &c. Stiff clays are the best for forming tunnels through, as they require less shoring and other supports than looser soils in some siliceous and argillaceous soils; the expenses of shoring and supporting the ground above, with the danger attending the work afterwards, is of more expense and difficulty, than at once beginning the work by open cutting, which in an instance or two has been obliged to be had recourse to, after many attempts at perforating such soils. The expense of canal tunnelling, as well as others, must vary as the earth varies through which it is intended to be made; in favourable circumstances, pretty accurate estimates might be formed; and as a reference, the following account, which is taken from Dr. Rees's Cyclopedia, article, Canal of the Tunnel at Blisworth, on the Grand Junction Canal, will suffice, as being the latest which has been finished, (Feb. 1805). "The internal width is 16 feet and a half, the depth below the water-line to the inverted arch which forms the bottom is seven feet, and the soffit, or crown of the arch, is 11 feet above the same line. The side walls are the segments of circles of 20 feet radius, the top arch one of eight feet radius. The side, or top walls, are 17 inches in thickness, or two bricks, and the bottom, or inverted arch, 13 inches in thickness, or one and a half brick, every fifth course of the top arch, and every eleventh of the side-walls is composed of two heading bricks, or wedge-like, one inch thick on the inside, and three at the back; also every fifth and eleventh course as above, (but between the courses of heading bricks), composed of bricks laid obliquely across the others, the front and back corners being cut off for that purpose in the making, for more effectually breaking the joints of the work obliged to be done in such short lengths. The mortar that was used, was composed of one bushel of Southam lime, (blue lias), and three of good sand. Six inches under the water-line, on each side of the tunnel, slide-rails, of five inches square, were placed to keep the barges off the walls, and fixed by pieces of oak let into the wall below them, which rails project nine inches from the wall, and have at every nine feet a chock of wood upon the rails for the bargemen to set their pole against for shoving their barges along." It is added, that "this tunnel was contracted for at 15l. 13s. per yard run. The soil principally through which it was made was a hard blue clay, with two or three thin rocks in it, sufficient headings had been executed several years before at the company's expense. The same contractors were paid 10½d. per cubic yard for excavating the deep cutting at one end of the tunnel, and 11d. a yard for the other. The expenses of driving the headings, were from 36s. to 42s. 6d. per yard run; nineteen shafts, or tunnel pits, some of them 60 feet deep, were sunk for the use of the above tunnel, which cost about 30s. per yard in depth, including the steining." From such data, very probable estimates may be calculated, taking into account the different prices of labour and materials where such a work is proposed to be effected. The success attending tunnelling having been generally complete for canals, undertakings of the same nature have been proposed for various other improvements in our inland communications. Highgate was fixed upon as one for this purpose, which certainly presented a spot in every way eligible for the undertaking, and from which the public might have derived considerable accommodation. The heading of this tunnel was began on the Holloway side of Highgate, and extended about 350 yards with about 30 yards of vertical cutting. The whole was marl and strong blue clay, with a compactness that required very little propping, every thing in nature was favourable to the success of this tunnel, and the work went on with adequate effect, till the arching commenced. It is too well known, that this arch has now given way, and it is for the engineers concerned in it to say, why.—It could not have failed by reason of the soils in which it was formed,—as their compactness rendered their bearing on the arch of little or no importance. The shape of the arch made it capable of supporting ten times what was ever upon it, if the bricks had received adequate attention in their bonding. If it failed for want of sufficient foundation, it is to be regretted: the inverted arch was not adequate for that purpose, as a very slight inspection will demonstrate. And if it fell down for want of support in this quarter, it must have been from the engineers' ignorance of the nature of the pressure in such arches:—Arches formed of common bricks, when they are to assume a large diameter, require the utmost attention in their construction. The brick of the common size is *too* small to make any figure as a voissoir in such arches, as it will not allow of falling into the radii of their curvature; if such arches exist, it is by virtue of the cement more than by reason of the shape of the materials of which they are formed. In the tunnel now making across Hyde-park, for conveying the superfluous water from the neighbourhood of Paddington, the bricks which are to form the arch, are moulded into the shape of wedges, and are called joggle-bricks, the form of the joggle-brick is previously determined by drawing its shape from the centre of curvature of the arch,

arch, of which it is to form a voissoir, and they may be varied, as the figure of the arch is composed of more than one centre of curvature; hence the parabolic arch will require joggle-bricks of one pattern for the top, and of another for the sides, such an arch being composed of different segments.

Bridges have continued to be erected through every succession of time, and are a leading point in developing the progress of science and the arts, as they appear generally well or ill contrived in proportion as they have advanced. Arcuation, within these last fifty years, has received deductions, arising from out of mathematical investigations, which has ranked it very high among the late discoveries made in science by the industry of the moderns. It has now been shewn that the voissoirs of an arch can be given that form, in relation to the whole matter surrounding them, as to produce an equilibrated figure; and this discovery has so far extended itself as to supply the principle by a table which sets forth its quantities to every species or degree of curvature. This table was formed by Dr. Hutton, and may be consulted by turning to Bridge, under the head of the article Architecture, part i. page 34. The Bridges, to which the attention of engineers are commonly called, confine themselves to simple buildings, applied to the purposes of a canal; they consist, most frequently, with us of wood, and their beauty consists in making them light, but adequately strong.

Of the different species of bridges the draw-bridge is the most common; it consists of the following particulars: *Plate* 1, *Fig*. 9, is the plan of a drawing-bridge; D, the canal to be passed. The foundations, right and left of the canal, are supplied either by brick-walls, built battering, or by a row of four or more piles of oak, forced down into the embankment, with a broad oak-rail on their tops, splayed away to receive the two *end-rails* of the platform of the bridge. B B the embankments to the bridge. G the platform of the bridge. E the vertical posts, fixed on the bank of the canal, a little behind the hinges of the bridge; on the top of these posts are two long tapering pieces F, called the balance beams, which turn up by means of hinges near their middle, the small ends being connected with the platform of the bridge by means of chains at their further end, and which the heavy ends of the balance beams are made to counterpoise. When such a bridge is required to be raised for a boat to pass it, it is necessary to take hold of the chains appended to the large ends of the balance beams, which, being only just counterpoised, are easily pulled up, and when raised, the chains are hooked to the upright posts, to prevent accidents, and the bridge remains suspended.

Bridges, called swivel-bridges, are sometimes made use of on canals; they are much more expensive, and may be easily put out of order by the want of attention in using them; they consist of a platform of wood covered with planks; which is made about half as long again as is required for the bridge: one end of the platform is made light and the other heavy, for the purpose of counterpoise, and the additional weight to the heavy end is produced by means of stowing large stones or pigs of iron at it, so that the bridge, when in its place, or at rest, may attain an equilibrium. At a point of about one-fifth of its length from the heavy end, a round plate is fixed, with an iron axis or pin standing up to enter a hole in the platform, which is prepared to receive it; and on this pin the bridge is suspended, and which is also its centre of motion; and in order to prevent impediments in turning the bridge round, a number of iron balls, two inches and a half, or three inches in diameter are let into the round plate, both above and below, to act as rollers to lessen the friction on the plates. The banks are formed with a kind of recess to receive the bridge when moved from across the canal. The two ends of the platform, in order to allow of this horizontal motion, are struck into two arcs, the centres of which are the axis or pin in the centre of the friction-plates. At Brussels, and in other parts of Flanders, they have a kind of drawing-bridges composed wholly of iron: they are made somewhat similar to our drawing-bridges, except that they are raised by a cast iron wheel with cogs; this wheel is about three feet in diameter, and is firmly fixed in the bank, and by being turned by a handle, raises the platform. It takes up much less room than our drawing or swivel-bridges, and answers every purpose. There are nine or ten to be seen at Brussels, constantly in motion, as ships or craft are passing up the canal. Some of these iron bridges are cut in two in the centre, with wheels in each bank, so that by working the wheels a few degrees a ship may pass the canal, by its masts entering through the space left by raising the two platforms. These kind of bridges are made necessary from the great width of the canals in comparison of ours. The occupation bridge, at Rotterdam, is of this last description, and consists of two separate segments, each supported independently; and when up for the craft to pass, a void is made between the meetings of the segments by which the masts enter. The convenience of such bridges is obvious, as the towing can go on without removing the line; foot passengers also can pass by the bridge while in motion, as the opening between the meetings is never so wide but a person may step over it. The canals in Flanders, Holland, and every part of France abound in ingenious light bridges: their drawing-bridges are on a scale the engineers of this country have not an idea: there are some over streams 120 feet wide, moved by wheels with more ease than our little ones of 20 feet are by balance beams.

The bridges of masonry on canals consist of one arch generally, with the difference only, of making its span as much more than the canal as to admit a towing path under it. The towing paths are made commonly on the lower side of the canal. The bridges over the canal at Paddington have towing paths on both sides, and this, when there is room to do it, is a great convenience; besides adding additional strength to the abutments of the bridge.—Guard rails should be fixed to the wings and approaches of the bridge, and also to the embankments under

under the bridge, to keep the boats from damaging the works.

Docks, from at first being only a simple contrivance at arsenals for the purpose of building or repairing a single ship, have extended themselves to a magnitude in capacity competent to contain whole fleets. The splendour of the docks created in London, and at many of the out ports, are a monument which excel the famous port Pireus in Greece, or Alexandria, in Egypt, as much, or more than we have excelled the Greeks and Romans in all the facilities to navigation, and the grandeur of our naval architecture. The Greeks and Romans no doubt have far surpassed us in all the elegancies of taste and invention in the fine arts: in these arts they have combined and given form to matter, which could have resulted only from a higher degree of feeling, united to juster notions of nature, than the coldness of our climate and habits can perceive, or hardly give power to copy. But if we are behind in the fine Arts, which, as mere copyists, we must be contented to be: in supplying all manner of facilities to commerce (in which we excel all nations, ancient and modern), in erecting the immense docks and warehouses inland, which we have done to receive and house safely the produce of the world, and to an extent adequate for that purpose: we have formed a monument at once of our genius, wealth, and skill, which will be as famous in the page of science as the monuments of Athens and Rome are now in the volume of the Arts.—A Dock consists in the first place of a bason commensurate to its intended purpose. A canal communicates therewith, supplied with an entrance lock and gates. The building of a dock embraces all the skill applied to buildings in water. The embankments are to be traced out in the same manner as is done for canal lines, by setting up bench-marks to indicate the plan upon the ground. The whole of the embankments of a dock are supported by walls of masonry or brick-work; and as the docks for ships require a great draught of water, they must be made in depth adequate to allow of ships of burden riding in them in safety: in consequence of which the depth of the docks must be great in comparison of canals. The London Docks are upwards of 20 feet deep. In raising the walls on the sides of such reservoirs (as they may be called), it will be obvious that the greatest care must be taken. The foundations of walls for works of this nature should be formed of double or even treble rows of piles; and the inside row, which runs parallel to the embankment, should be grooved on their opposite sides, and be forced into the ground as close together as possible; and after being so driven, stiles of yellow fir wrought should be driven down into the groove made in each pile, so that the whole inside piling may form a continued chain throughout its whole extent.—The planking to form the platform for the wall, should be all scorched previously to being laid upon the heads of the piling, and the joints or meetings of the planking should be crossed or dove-tailed together. If the walls be to be built of bricks, care should be taken to have them of the best quality, and as square and even as can be; and in order to strengthen their bond in the wall, tiers of Dundee granite should occasionally be incorporated. The walls themselves should be for a height of 20 feet, of 15 bricks in thickness at the bottom, on planking racking-back on the side next the earth embankment, and battering on the inside of the dock, with tiers of bond of Dundee granite at every 20th course throughout the height. The slope of the wall should be in proportion to a scale before recited for lock walls of canals; and a curvature or swell should be formed in the inside section of the wall in the proportion of two inches to every six feet: the walls should, finally, finish at their tops to four bricks in thickness, and the whole be crowned by blocks of Dundee or other granite, as a coping.—The mortar used for these kinds of works ought to be particularly looked after, in order to its being of good quality, or very little solidity will result to the work. The ground stone lime with washed siliceous earth, the former as fresh as possible, is the most likely to prove a good cement. The Roman cement, or Parker's, is of great utility in some parts of dock-works. The docks, as Helveotsluys, are formed with clinkers cemented by Dutch-tarras: it has tiers of bond traversing at every 4 feet, vertically, composed of black marble neatly wrought, which in every other stone goes quite through the wall, and the top of the wall is coped with large slabs of the same marble. The work of these docks from the smallness of the bricks (about 6 inches long, 3 in width, and one and a half inch in thickness;) and the joint having very little cement in it, makes the whole appear uncommonly neat, and which is not less solid. These docks are about 18 feet perpendicular in depth, the side slopes from their base 5 feet 8 inches.—The opposite end to the canal of communication is formed into a bow or crescent. The walls all round this dock have a slight swell or curvature in their height.—The canal leading to a dock generally branches out of its side, and is walled in a similar manner to the dock itself, and at its upper end or head is contracted by the walls being bent into a circular shape till they meet or intersect the wing walls of the lower end of the chamber of the lock. The lock is the pound or chamber through which the ship or ships enter from the sea or river to which the dock is contiguous: to docks of consequence the locks are made from 30 to 40 feet wide, and about 18 feet deep and 150 feet long. They have gates at both ends, which require the utmost skill in contriving them for tidal-rivers. The bottom of the lock is formed by an inverted arch of masonry in a similar manner to that of canal-locks, except on a larger scale, and of course of a more ponderous nature. The walls are raised battering similar to those of the docks, and, finally, coped at their tops, weirs, syphons, waste-gates, and culverts, are all of use to dock-work, and must be called in as the nature of the situation requires them. Wherever it is intended to form docks a large site of ground should be selected, in order to admit of abundance of room for all kind of stowage and ware-

houses

houses being built thereon; for without abundance of room very little accommodation can be expected by creating docks on such sites. The necessity of room in such concerns will more obviously appear by considering the space occupied by the docks themselves in the three great concerns now effected in London.

The London docks, which were built under the direction of Mr. Rennie, consist of two docks, with basons, canals and locks. One lock is 1,260 feet long, and 690 feet broad, containing 20 acres, and the bason equal to three acres, the whole capable of containing 230 ships: the other dock, for outward bound ships, is of a similar dimension, and they communicate with each other by means of locks, and also with the Thames, at Limehouse. The warehouses and offices for the clerks and keepers surrounding these docks are of a magnificent description, and afford abundance of protection and comfort to all the various stowage and persons connected therewith,—the architect is Mr. Alexander, and the estimated expense of the whole is one million and a half sterling, and they are now nearly completed.

The West India docks, to which Mr. Jessop was engineer, were begun in 1800, and are divided as before into two docks, basons, and locks. The homeward-bound dock is 2,600 feet long, and 500 feet broad, and will contain 300 sail. The outward-bound dock is the same length as the homeward-bound, but only 400 feet broad; they join each other by means of locks, and at the end next Blackwall, with a bason 6 acres in extent, with sloping embankments, and which has a connexion with the Thames by a lock. At the other end of the docks, near Limehouse, there is another bason of about 2 acres, at which vessels go out: this bason, as well as the docks, are wholly surrounded by walls of brick.

The East India Company's docks are also of great importance, being, with the warehouses, formed in a grand style: the late Mr. Holland was the architect. The dock for unloading inwards is 1,410 feet long, and 560 feet broad. The one for loading outwards is 780 feet long, and 520 feet broad. The entrance bason occupies a space of 2¼ acres. The lock of communication is 210 feet long, 48 feet wide, and the clear depth of water 24 feet. The whole of these docks are also surrounded by walls of great substance, and finally coped with masses of granite stone.

These several works are appendages to our national importance, and are well calculated to inspire the living, who may view them with astonishment, and future ages, with veneration.

After docks there is another appendage equally flowing from our great maritime power, and which consists in creating artificial piers, or break-waters, projecting into the sea for the purpose of giving security to vessels at anchor against the violence of winds and currents, at such places where it has been deemed eligible to form ports or places for ships to anchor at. The late Mr. Smeaton was the first engineer amongst us who embraced, in the boldness of his genius, the requisite science for such undertakings, which has had the effect of establishing his reputation beyond the chance of a failure. Every part of the country exhibits something of this man's contrivance, either in canals, bridges, harbours, or machinery; and of course, every thing from such authority is of importance, inasmuch as it may teach those who have now to follow him how true fame may be acquired and become imperishable. His papers have at last been collected and are now in train for publication, comprising all his reports, together with their estimates of all the several public works that he conducted, accompanied by engravings, &c.*

It is extremely difficult to give precise ideas for buildings connected with sea-ports and their harbours; for in such places the natural vicissitudes are what offer the impediments, and they must be met in the various ways in which they present themselves by the skill and enterprise of him to whom such buildings may be confided. There have been piers or break-waters erected at many of our ports extending an immense distance out into the sea; for instance, at Sheerness, Ramsgate, &c. and there have been also several on the opposite coast; the one at Cherbourg is pre-eminent for boldness and genius. Some account of Mr. Bentham's plan which he adopted at Sheerness Pier will be seen under the head of Buildings in Water, in our article Masonry. The great national work now undertaken in Plymouth Sound is perhaps on a scale far beyond any thing of the kind ever set about in the world before. Messrs. Rennie and Whitby are the engineers, and in such hands very little doubt can be entertained of its complete success. A time of peace, if ever it arrive, might have been the most eligible for an undertaking of so extensive a kind, as allowing the means with better grace than at present; but it is begun, and if it be persevered in, the means must and will be furnished. In the reports laid before Parliament of this break-water is the following opinions and estimates, given in by Messrs. Rennie and Whitby, and on which the work was ordered to be commenced. Speaking of the Port of Plymouth and the proposed break-water, they say, "There are, properly speaking, three entrances for men of war into Plymouth Sound: viz. one on the west side of the bay, bounded by a long cluster of small rocks called Scot's Ground, and on which there is only from three to four fathoms at low water; and on the East by the Knap and Panther, on which there is about the same depth of water. This channel is about 500 fathoms wide, and the general depth is from five and a half to six fathoms at low water. The middle channel is bounded by the Knap and Panther on the West, and by the Tinker and Shovel on the East; it is about 300 fathoms wide, and the general depth of water is from six and a half to eight at low water. From the above description, it appears that a large part of the middle of Plymouth Sound may be said to be shut up by the Shovel and St. Carlos Rocks, we mean as a channel for

* This work is now publishing by Longman and Co. with engravings by Lowry, in 3 vols. price 7l. 7s.

large ships. Of course, any works that may be constructed on these rocks will be no obstruction to large ships going in or coming out of the Sound. A question however will arise, whether if any works were to be extended beyond these rocks they might not prove injurious? On this subject the engineers add the following opinion, which they trust will prove satisfactory; and that no injury whatever will arise from the extension of these works beyond these rocks. "It is," say they, "a well known fact, that whenever a given quantity of water flows through a channel, the depth generally increases (unless the bottom be rock) in proportion as the width be diminished. Now if a work were to be formed in any part of Plymouth Sound, so much of the water-way or entrance as would be intercepted by that work would obstruct the current of the tide, and oblige it to pass through a narrower space: this would increase the velocity and occasion a greater scour, so as to deepen the bottom. If, therefore, a pier or break-water were to be constructed on the Shovel Rocks and extended to the westward, so as to shut up in part the channel between them and the Panther, and also to shut up or narrow the spaces between St. Carlos Rocks and Andurn point; the tide being then confined to a narrower space, the velocity of the current would be increased and their channels deepened. We are therefore decidedly of opinion, that if a pier or break-water were to be constructed in Plymouth Sound, having its Eastern end about sixty fathoms East of St. Carlos Rocks, and its Western end about 300 fathoms West of the Shovel, forming in the whole a length of 850 fathoms, it would improve instead of injuring the entrance to Plymouth Sound; and would with another pier, which we shall afterwards mention, completely shelter it from all storms, without there being any danger of its lessening the depth of water in the Sound, or any doubt of the practicability of executing the work. We propose that 500 fathoms in length of the middle part of the pier or break-water shall be straight, and that 175 fathoms at each end should be inclined to the straight part in an angle of about 120°; these inclined ends will not only shelter a greater extent of the Sound, but will to a certain degree prevent the increase of the sea from agitating the water. The eastern end, or that which points to Bonvisand Bay, leaves the Eastern point of the Sound apparently too much exposed to south-easterly winds; and although we are inclined to think that even with such an exposure nothing need be feared, yet as there is a ready method of preventing any such danger we are unwilling to leave the matter in doubt, and therefore propose that a pier shall be extended from Andurn point towards the great break-water of about 400 fathoms in length, and having an inclined kant similar to the head of the great break-water, and forming an angle of about 120 degrees with it. These two inclined kants or heads will reflect the waves in such a manner as to prevent them from passing in any material degree through the opening between them, and will thus shelter the Sound. These break-waters will, it is remarked, enable fifty sail of the line to ride in safety in Plymouth Sound in all winds and in any weather, and with ample room to work out at one or other channel as the wind may suit. The mode of executing this great work follows next in order:

"The best manner of constructing the work will be by large blocks of stone thrown promiscuously into the sea, in the line of the intended break-water, leaving them to find their own base. These stones must be large; otherwise, with such a swell as in the Sound in stormy weather they would not remain in the place where they were deposited. From observations which we have made, stones of from about one and a half to two tons each will answer the purpose. Where the water is five fathoms deep the base of the break-water should not be less than seventy yards broad, and at the top ten yards, at the level of ten feet above the low water of the ordinary spring tides. It may, however, on trial be found necessary to carry it higher; but this will be ascertained during the execution of the work, when the effects of the sea on it will be seen, and it may then be carried higher if found necessary. It may be a question whether this additional height shall be executed with cut or rubble stone, which it will be also time enough to decide when the break-water is raised above low water. We have in our estimates supposed this part of the work to be done with cut stone. It is not an easy matter to calculate correctly what quantity of stone will be wanted for this great work, not only because the sea may form a more extensive base than we have supposed, but because the bottom being very uneven, and no correct section of it having been obtained, we have therefore made considerable allowance. Thus, suppose the great break-water to be 850 fathoms in length, ten yards broad at the top, and ten feet above low water of spring tides, and having a slope on the South or sea-side of three horizontals to one perpendicular, and on the Sound or land side one and a half horizontal to one perpendicular, there will be required about two millions of tons of stone. If the pier from Andrun Point is built from the shelving rocks without the Point and not carried close to it, there will be required for this work 360,000 tons of stone."

To this Report is added the following estimate of the probable expense of executing the break-water, with the addition of erecting two light-houses on each extreme point of the straight, or centre part of its superstructure.

Estimate of the probable Expense of a Break-water and Pier for the sheltering of Plymouth Sound and Bouvisand Bay.

	£
To 2,000,000 tons of lime-stone, in blocks of from 1 to 2 tons each in weight in the breakwater, 7s. 6d.	750,000
To 360,000 tons in the pier proposed to be built from Andurn Point, 7s. . . .	126,000
Contingencies 20 per cent.	175,200
	1,051,200

Estimate

Estimate of the probable Expense of a Cut Stone Pier and two Light-Houses, to be built on the top of the Great Break-water.

	£
To 42,000 cubic yards of masonry, in the out and inside walls of the pier, 27s.	*44,700
To 62,000 cubic yards of rubble, filling between in the in and outside walls of the pier, 6s.	18,600
To paving the top of the pier with large blocks of stone, 8,500 square yards	22,950
To two light-houses, with reflectors and argand lamps	5,006
Contingencies 20 per cent.	28,650
	119,900

To this report has been subjoined the opinion of Mr. Jessop, an engineer of great eminence and experience, entirely concurring in the plan of Messrs. Rennie and Whitby. Nevertheless Mr. Bentham, who has been employed in some works at Sheerness harbour, and who has invented a new mode of erecting masonry in and under water, has endeavoured to recommend his ideas to the notice of Government for this break-water. Mr. Bentham's invention consists in preparing masses of stone, intended as piers, to be sunk under water with sufficient vacuities in them, to render them specifically lighter than an equal bulk of water; a mass so prepared is sunk, by letting the water into its vacuities. The bed of the river, or harbour, being previously prepared to receive it by machinery of the description of ballast heavers, that it may ground level. Should the mass not so ground, it is raised by pumping the water out of its vacuities, by which means it is again raised, and by letting in the water again it is lowered, and it may be so raised and lowered till it ground to the satisfaction of the engineer. This is ingenious, inasmuch as it performs by means of the mass itself, the whole operation of caissons, or water-tight boxes, the assistance generally had recourse to for erecting piers in water; but a caisson would be of no use in Plymouth Sound. If Mr. Bentham's hollow stones are, however, as he has more than one plan for this break-water, and as the ideas of intelligent men are always of utility, we shall subjoin the following extracts from his report on that subject. Speaking of the plan of Messrs. Rennie and Whitby, he says, "That such a work, even supposing sufficient precaution to have been taken to prevent any injury to the harbour during the execution of it, and that the work were completed in its greatest perfection, would nevertheless by opposing throughout its extent a complete interruption to the existing water, occasion such eddies in the wake of the work, and such an increased action on the bottom and sides of the parts left open, as could not fail of forming shoals more or less injurious according to the nature of the soil and other local circumstances. By one of my plans, a double row of cylindrical masses of stone-work, built in my new mode, are designed to be deposited in the direction most suitable to a break-water, (which probably would be different from that fixed on by Messrs. Rennie and Whitby), in such a manner as to leave an interval between each two masses above, equal to their diameter, and that the masses of one row should be placed opposite the intervals in the other, so that while these two rows together form a complete obstacle to direct the course of the waves, the tide, or current, would be allowed to pass freely between them throughout the whole extent of the break-water, as also boats, or even small vessels in moderate weather. According to another variety of this mode, a single row of masses, more in the form of the piers of a bridge, might be deposited at a greater distance from one another, and other masses of stone might be deposited upon them, so as to form a kind of bridge, but differing from ordinary bridges, inasmuch as that instead of the arch between the piers rising above the water, the bottom of the parts intermediate between the piers, would be kept sufficiently under low-water, as to afford a complete obstacle to the waves to the required depth, but leaving nevertheless very ample space underneath for the constant passage of the tide, or current. The upper part of such a break-water would be sloped on the side towards the sea, so as to afford an inclined plane for the waves to expend themselves upon in mounting: the interior sides of the masses, according to either of these modes, would be perpendicular, and by being hollow, might be converted to various useful purposes, whereby a compensation might be obtained to a considerable part of the expense." He adds, "in considering further, that a diminution of water-way is objectionable, and that raising works in masonry, is creating artificial rocks, against which ships are as likely to be carried to their destruction as against natural rocks; I should propose in preference to make floating break-waters in separate parts or floats of wood, because that material is sufficiently buoyant, without the need for depending on any cavities which might be liable to be filled with water, to make the floats of a triangular, or rather a prismatic shape, and to hold them in their places, by means of iron chains, &c." In several other observations of a general nature, is appended the estimate for executing the works by the several plans he has suggested. The total of each is, viz. by the plan in masonry, as before described, 284,648l.—by that of wooden-floats 201,826l. If there be no other merit to recommend Mr. Bentham's plan, than its comparative cheapness, that even ought to entitle it to consideration. The difficulty in employing his hollow masses, it is imagined would be much greater than he conceives. Six or seven fathoms low water, with a rocky bottom, would present such obstacles to getting them into their places firmly, (even if at all,) as in some measure makes the idea appear

* There appears an error in this item amounting to 12,000l.; how it could have arisen cannot be explained in this place; but it is to be hoped the estimate was not drawn up generally with so great a want of accuracy.

pear impracticable. To prepare the bed of Plymouth Sound with ballast-heavers, or any other machinery to receive the base of these cylindrical masses, is barely possible, and without a base being previously prepared, and that tolerably even too, such cylinders would not stand. If there did not appear an impracticability in doing any thing at the bottom of the Sound, the engineers employed would not deem it eligible to throw in stones promiscuously into the line of the work to find their own base, as they would certainly rather prepare a base for them than waste materials and labour, with a chance of much less solidity, than producing the foundation by regular and ascertained principles. The plan by floating rafts might be useful; but it is more happily adapted as a temporary expedient, than as a great national undertaking. To make Plymouth Sound a place of greater safety than it is admitted to be at present for our numerous fleets, and which is supposed to be the best adapted port for their security this island has to boast, renders such an undertaking of the first importance. If the proposed break-water has the effect of improving it, and at the same time giving to it the advantages expected from it, the cost will be but a secondary consideration.

The erection of beacons and light-houses is a branch of the royal prerogative. The king has the exclusive power, by commission under his great seal. He can order them to be erected, not only upon the royal demesnes, but upon the lands of the subject; which power of the crown is usually vested, by letters patent, in the office of the lord high admiral. And if the owners of the land, or any other person, shall destroy them or take them down, he shall forfeit and pay 100£., and in case of inability to pay it, be ipso facto outlawed. By statute, 8 Elizabeth, c. 13, the corporation of the Trinity House were empowered to set up any beacons or sea-marks wherever they might think them necessary, and in them now almost the whole business, respecting the management of beacons, light-houses, &c. is vested. The Beacon is a simple contrivance of very early origin, as we find frequent mention made of such objects, not only in the scriptures, but in ancient history, and also in the early part of our own history. Beacons consisted chiefly in erecting on high places marks whereon were fixed barrels containing pitch or other combustible matter, which, by night, operated as a warning by being lighted, and by day they gave notice of the approach of an enemy, by the volumes of smoke emitted. By the discovery of gunpowder, such expedients have been discontinued; as rockets and other contrivances are found to answer the purpose infinitely better. A light-house is a different kind of building to a beacon, inasmuch as it requires greater constructive excellence in the erection. Its use is chiefly to warn mariners, when navigating in the night, from approaching too near certain parts of the coast known as dangerous, either by rocks, shoals, or currents; and it is also a land-mark by day. Such structures are of great national importance, and as such, cannot receive too much attention, either in fortifying them in the most substantial manner, or supplying them with the best lights. A light-house, as now erected, consists of an upright shaft of masonry or brick-work, built hollow in the inside, in which are winding stairs leading to its summit. The top is generally surmounted by a cornice of stone, with a space left sufficiently large to admit a single person safely to walk round upon it. On the top of the whole fabric is erected a lantern, often from 12 to 14 feet high, and 6 or 7 feet in diameter, in the inside of which is a frame, to which are suspended, in various angles, and in as many elevations, a number of lamps and reflectors; the lamps vary from 10 to as many as 15 in some light-houses. Such a body of light, and that reflected with the greatest power on an immense height, as they most frequently are, creates a surprising effect, which is discovered at sea by mariners when many leagues off, and which enables them to shape their course accordingly.

The Eddystone light-house was erected by the late Mr. Smeaton, and in this is employed, perhaps, more ability than in any similar structure in existence, arising out of the difficulty of erecting any thing in such a perilous situation. "Mr. Winstanley began a light-house on the Eddystone rock in 1696, which he was four years in finishing, which was formed wholly of wood. The following notices respecting his operations may not be unacceptable. The first summer was spent by Mr. Winstanley and his people in making 12 large holes in the rock, and fastening as many irons, to hold the future work. In the course of the next summer, a solid body or round pillar, 12 feet high, and 14 feet in diameter, was completed. In the third year it was increased to 16 feet in diameter from the foundation, and the whole building was raised, which was 80 feet to the vane. In the fourth year, the diameter of the pillar was encompassed in a new work, 4 feet in thickness, and the building raised 40 feet higher, when the light was exhibited." This building was formed almost wholly of timber, and it did not meet with any accident till 1703, "when standing in need of repair, Mr. Winstanley came to see it; and having been among his friends previously to going off with his workmen, to view the repairs, the danger was intimated to him, and that one day or other the light-house would certainly be overset: he replied, "He was so well assured of the strength of his building, he should only wish to be there in the greatest storm that ever blew under the face of the heavens, that he might see what effect it would have on the structure." Mr. Winstanley was but too amply gratified in his wish; for while he was there with his workmen, that dreadful storm began, which raged the most violently upon the 26th of November 1703, in the night; and of all the accounts of the kind which history furnishes us with, we have none that exceeded this in Great Britain, or was more injurious or extensive in its devastation. The next morning, Nov. 27, when the violence of the storm had in some measure subsided, that it could be seen whether the light-house had suffered by it, nothing appeared standing, but, upon a nearer inspection,

inspection, some of the large irons whereby the works were fixed upon the rock; nor were any of the people, or any of the materials, ever heard of afterwards."

The next light-house built on the Eddystone, was by Mr. Rudyerd: it was finished in 1709, and destroyed by fire in 1755. It was now deemed eligible to erect a building, if found possible, not so likely to meet its destruction, either by the violence of the sea, or the effect of fire, as both the former had been destroyed by one or the other. Mr. Smeaton was now employed, and, contrary to the received and popular opinion, that no building could be made to stand except one formed of wood, he shewed a contrary design, and boldly projected a light-house of stone; and, as he himself says, "he shall endeavour to form it and put it together, so that while, by a similarity of construction, no man shall be able to tell him at what joint it should overset; for if at any given height the uppermost course was then completed safe, it became more safe by another course being laid upon it; and though that upper course were somewhat less in weight, and in the total cohesion of its parts, than the former, yet every course, from the first foundation, was less and less subject to the heavy stroke of the sea." This building was formed to resist the effect of both wind and water, and these acting on it occasionally in a most tremendous way. The light-house is wholly of cut-masonry, about 16 feet in diameter at bottom, and diminishing upwards conically; it is 73 feet 6 inches in height, measuring from the rock on which it stands to the top of the cornice. Mr. Smeaton chose a curve for this structure with its concavity turned outwards, and the judiciousness of such a choice is now fully established. From the top of the cornice to the base of the lantern is 7 feet 6 inches, and from thence to the summit of the ball 17 feet 6 inches, which together make a total height for this structure of 97 feet 6 inches.

The form of such buildings has involved considerable intricacy of mathematical investigation. M. La Grange has calculated that a cylinder is the strongest form for resisting flexure, which is contrary to the known fact, and could be only deduced from the intricacy of the investigation. If it were calculated what would be the best form for a wooden column, which to a certain depth was always to remain exposed to the water, it would be found that a cone or pyramid would possess the greatest possible strength for supporting the velocity of the water. And for resisting the wind also, the figure must be made more acute than it would otherwise be necessary for resisting the water only. For withstanding a force which tends to overset the building, the form in which the weight gives the greatest portion of resistance is that of a conoid, or a solid of which the outline is a parabola concave towards the axis. And for procuring, by means of the weight, the greatest quantity of adhesion of the parts, the form should be cylindrical. To effect with success any works exposed to all the multiplied events arising out of the effects of nature, will require a tedious investigation, which will involve all the skill and foresight of the engineer to whom such works may be confided.

The forming of roads is of considerable importance to every well-regulated country; and although it has been, perhaps, too much neglected in our own, it is now receiving that attention which its importance requires.

Roads are divided into military-roads, double-roads, and subterraneous-roads.

The leading feature in marking out a road consists in selecting such parts of the country as will enable it to reach the point to which it is intended to terminate by the shortest routes, with as little deep-cutting of hills as possible; and if that cannot be avoided, to so arrange it, that the soil removed be easily conveyed to those places which most require filling up. The Romans took great pains in forming their military-roads, as numerous vestiges still remaining attest: the Via Appia is the most remarkable; it was, according to Procopius, five days' journey in length, which Leipsius computes at 350 miles; it was paved with hewn free-stone, which has remained almost entire for 1,800 years. All the roads on the continent are, in some measure, formed after the manner of the Roman military roads. The roads leading to Paris, in almost every direction, are divided into three divisions or parts, and planted with as many rows of trees. The centre division is raised considerably above the two roads on its sides, or lateral roads, and is finished by a pavé. This road is intended for public carriages, and on which they are obliged to move, under a heavy penalty. The lateral roads are made up of limestone, and covered with screened gravel, similar to our own manner. These roads, right and left of the centre road, are used for the noblesse, and persons riding in their own carriages. The centre road is adequately wide to admit of three or more carriages abreast, which allows of crossing without inconvenience; and the other two roads are wide enough for one or two carriages to move easily, but are so regulated, that no carriage is found on the wrong road: hence no interruption arises, as the travellers are always found on their own road. There is also a walk on each side of the two lateral roads, for foot passengers. In Normandy, the apple tree is the one selected for planting the road sides; and in the season the great abundance of the fruit is astonishing to travellers. The roads in France are a considerable ornament to the country, and at all the approaches to the capital, they are ornamented by elegant barriers, with spacious buildings for collecting the duties. Some of these buildings are in the shape of antique-temples, others round, and being wholly formed of free-stone, add greatly to the splendour of the approaches to Paris. The French consider a straight line as the most eligible for a road; hence all their roads appear a complete vista, tedious, no doubt, to a traveller, but it enables him to reach his journey's end by the shortest means; a thing of some importance in a great country. In England the roads are as they were left from time immemorial, and partake greatly of the general feature of the landscape of the country,

country, which they, in no small way, enliven and support. Our roads, such as they are, seem to partake not in the least of art, which is the opposite to those on the continent; and whether we ought to uphold our own fashion in road making, if no great public inconvenience arises out of it, remains with ourselves.

A road should always have a good bottom; and as most parts of the country abound in limestone, the most eligible material for making one, it certainly would be easy to accomplish that object. On the top of the limestone, screenings of gravel would be the most desirable covering. The great Bath road is so formed. Every road ought to be well drained of the waters falling on it; and also, those waters which may occasionally overflow it, all should find a ready exit, through culverts formed on its sides, or under it; for water lying on roads, particularly such as ours are, more dilapidates them than the traffic. There has been, at different times, many experiments made to uphold the roads, for the wear and tear has been found so great, as to prevent their being kept in tolerable repair: out of these experiments, which have been more directed to the carriages going on them perhaps than the form of the roads themselves, has arisen several ideas, such as the making of the wheels of greater width, and of altering the line of draught of the animals working in the carriages, putting cylindrical wheels to our heavy waggons instead of those of the present fashion which are conical; and one projector proposed, in order to make the line of draught easier, to put the highest wheels of his carriages foremost. Mr. Cummings, to whom the committee of the House of Commons particularly referred on this subject, did not, after deliberation, deem it eligible to give their support to any of the numerous plans suggested; and, of course, the alterations projected were not attended to, and our roads and carriages remain precisely as they were, but partaking of the natural improvement arising from out of the ingenuity of the people.

Iron or rail roads follow last in order. The origin of which may be traced back to the year 1680. About that period coal came to be substituted for wood as fuel in London and other places: the consequence was, that at the mines the greatest inconvenience accrued in conveying the coal from them to the ships, as well as immense expense in horses and machinery for the purpose; to remove which, waggon roads were made, consisting of wooden rails or ledges, which the waggons were formed to move upon, and from out of which improvement it was found that a single horse could easily draw a waggon on these rails, which previously required three or more horses to be employed to effect by the common roads; and it was also drawn more quickly, arising from laying down the frames upon an easy descent, which was always done.

In 1738, this improvement was farther improved by substituting cast-iron rails instead of the old wooden ones; but owing to the old fashion waggons continuing to be employed which were of too much weight for the cast-iron, they did not completely succeed in this first attempt. However, about the year 1768, a simple contrivance was attempted, which was to make a number of smaller waggons and link them together; and by thus diffusing the weight of one large waggon into many, the principal cause of the failure in the first instance was removed, because the weight was more divided upon the iron. In 1797, these roads having stricken the minds of intelligent men as of great importance, numerous essays appeared* setting forth their utility, and as many plans for rendering them of permanent construction. Hence cast-iron rail-roads became a second desideratum to canals, excepting only that the invention is due to Englishmen. After this time the cast-iron railways began to be constructed as branches to canals, and in some places as roads of traffic from one place to another, established upon permanent principles, so as to produce a permanent revenue to the undertakers. In surveying a line to set out a rail-way upon, it will be necessary, as a preliminary step, to ascertain as accurately as the nature of the thing admits, the quantity of lading expected to traverse each way upon its line; because in forming the slope or descent, this will be the data on which to ground a medium for effecting the required purpose most easily. If it should turn out that as much lading is expected one way as the other, with a preponderance at periods only, the railing must in such a case be set out in levels or in lines nearly level, and the ascent and descents made by planes inclined accordingly. Previously to beginning any part of the work, that is of laying the sleepers, &c. for the iron-rails, a rough sketch or section of all the different routes intended to be passed by the rail-way should be made, from which, and a view of the ground the engineer will be enabled to determine the place, and also the extent of the inclined planes which will be required in passing the steeper parts or the rising ground to which these planes are to be employed: it will always be desirable to get them as short as the site of the place will admit. In tracing out the line of a rail-road, the following method is pursued by our best engineers: they begin at the highest point, using a chain (of 100 links), and also berms, or bench-marks, and targets as they are called. The chain is stretched out upon the ground with one end being held at the point of the deepest turn, and the other turned round upon the face of the descent, until a *point* marked by this end is found, which is one link lower than the upper end, or nearly so. The chain is still carried forwards till its hinder end reaches the point last determined. The other end is then moved, and another point is ascertained one link lower than the last, and the operation is so continued, by which a line having the regular descent of one link to each chain will be traced out on the site of the intended rail-road." The bench marks are to be put in at each successive observation to mark the place found, and if it turn out irregular and crooked, the operation must be again repeated till the line appear more regular and without any sudden bends or crooks which must be always removed

* See Dr. Anderson's Recreations, Nicholson's Journal, Repertory, &c. &c.

and

and made undulating and easy, which will prevent unnecessary friction in the wheels of the carriages against the ribs of the rails. The rail-road when first marked out has a stake or mark set up at every chain in length; and these marks are the guides by which the workmen begin the operation of putting down the roads. When sudden valleys present themselves approaching to higher ground, it will be necessary so to conduct the line as to cut into the hill at each side, and the cutting from the latter will be useful in raising the road-way of the former. On approaching rivers or brooks which it is determined to pass, it will be necessary to keep up the rail-road to a higher-level by embankments, and on passing the water to raise a platform on purpose for it, composed of piers of masonry or columns of iron, with a covering of iron also to receive the rails; or a bridge altogether similar to an aqueduct bridge will answer the purpose. Railways may be divided into single and double: by the former are understood when a single road only is formed; by the latter, when two or more are made for the ready passage of waggons up and down the road. Single roads are generally made, including horse and attendant paths, four yards wide; and double ones vary from six to eight yards wide, exclusive of all the common appendages to such roads of drains, fences, &c. &c. In forming permanent rail-ways stone sleepers are necessary. These consist of pieces of good sound free-stone with their upper faces wrought fair, and should weigh from 150 to 200lb. each, with their ends which come together wrought smooth, so that the joints may be firm and close. The work of setting the sleepers must commence as soon as the road has received a tolerable surface in point of regularity. In cases in which there has been much making up or embanking the ground, short piles (*as shewn Plate 2, Fig. 7,* B B) should be driven down to receive the stone-sleepers, taking care to let the head of the pile come exactly under each meeting or joint of the stone-sleeper.

In commencing the work of laying down the stones, great exactness will be necessary in order to the iron-rails laying firmly on them; when one of the stone sleepers is laid in the proper place for one side of the rail-way, and nicely bedded and rammed down, another is to be laid at four feet distance from it, and bedded in a similar way. When these two stones are laid, they will operate as guides for proceeding in laying more stones, right and left, which should be carried forward together. A A, *Plate 2, Fig. 7,* represents the stone sleepers; B B the piles or blocks for supporting the sleepers in infirm ground; C C the sections for the cast-iron rails. Every tram or rail-road must be provided with passing places; a passing place consists in forming large plates of cast-iron, in such a manner as to admit of common rails being joined to them, and which will allow the waggons traversing the road to pass off into another or adjoining track. *Plate 2, Fig. 8,* shews a passing place for a double rail-road drawn to a quick sweep: but the turning or passing place need not be of such acuteness in general, but may follow a more obtuse shape, as best suits the nature of the place to be passed. *Plate 2, Fig. 8,* represents the plan of the two meeting cast-iron plates, D D; these plates should be accurately modelled in wood for the founder; and they should be so adjusted as that one model may serve for as many passing places as possible on the line of the proposed road; F F shews the joints where the common rails meet the passing ones; E E are moveable iron tongues placed in the centre of the passing plate; D D, which allow, by turning them round on a centre, of being removed to either side of the plate to keep the wheels of the waggons in the track required; so that a waggon may go on either side of the road by putting the tongue in the opposite direction. The side rails are shewn at G G; these consist of common side rails, except only that they must be modelled and founded to the intended shape of the passing place. H H shews the horse-path of the rail-road at the passing place. *Plate 2, Fig. 9,* exhibits a single length of a common rail for a road with its projecting margin; K to keep the waggon wheels in the track; as also the grooves, I I, through the ends or meetings to allow of their being fastened to the stone sleepers. The common method of fastening the cast-iron rails to the stone sleepers, consists in previously making in the stone an octangular perforation opposite to every joint intended in the cast-iron rails, into which a trunnion of good sound oak is fitted, with the grain of the wood presenting its section uppermost. The perforations to receive the oaken trunnions should be made quite through the stone, in order to prevent the effects of the frost, which, if not through, the water laying in the hole, will become frozen, expand, and shiver the stone into pieces. When the iron rails are nicely arranged upon the bearers or sleepers, they are to be fixed down by driving an iron key pointed at its lower end, so as to allow of its being driven into the oaken trunnion; the iron key has a head projecting similar to the letter T; and its lower shaft is made exactly in size to fill the void or groove left in the ends of the iron rails, as shewn at I I, *Fig. 9.* The common cast-iron rails for roads are formed in lengths of about three feet each; they are made about four inches wide upon the flat, or that part intended for the wheel of the waggon to move upon, and which is about one inch in thickness, sloped off a little to the horse-track: the projecting rim rises two inches and a half from the flat or bottom of the rail; in its centre forming the segment of a circle projecting upwards about an inch only at its meetings. (*See Fig. 9.*) The cast-iron plates at the passing places should be made somewhat stronger than the common rails, as at the passing places there is the greatest wear and tear upon the whole line. The iron moveable tongues, E E, *Fig. 8,* should be of wrought iron, and made about two feet six inches or three feet long, standing up upon the plate equal in projection to the highest part of the rim, K, of the common rails. It should be on a good strong axis or pin, that it may be strong and yet allow of being easily turned round, which it will

will require to be every time the waggons are passing by the different tracks up and down the rail-way. In passing deep descents, pieces of cast or wrought iron must be provided, called sledges or slippers; these are provided to be placed under the wheels of the waggons to prevent their too rapid descent, and are similar in principle to the same kind of instrument made use of and appended to our road-waggons, for putting under the wheels on their going down a hill. When the whole iron rail-way is fixed, and levelled to the satisfaction of the engineer, it will be necessary to begin to prepare the horse and attendant paths; the foundation of the former should be, if possible, composed of good lime-stone broken into small fragments, and strewed to the consistence of at least from 10 inches to 14 inches in thickness, rather convex towards the centre of the path, upon this large screenings of gravel should be laid: the attendant path should be firm and regular, with a gravelly surface. The horse-track and rails ought to be always kept clear and free from soil, which is constantly collecting on rail-roads of great traffic; and they ought also to be properly drained and kept dry at all seasons of the year; as on this, in a great measure, will depend their substantiality, and of course, their utility.

With respect to the waggons employed on iron rail-roads, those in most general use are so constructed, that their weight, including their lading, does not exceed three tons and a quarter. This is found by experience to be the most eligible size: as the rail-roads retain their shape without much dilapidation, by the use of waggons equal to such weight. The wheels of the waggons are made of cast iron, two feet five inches high, having twelve spokes, which increase in width as they approach the hub, or centre of the wheel. The hub is eight inches long, and receives an axle of wrought iron, the rims of the wheels are two inches broad. The axles of the wheels are fixed at two feet seven inches distance from each other; the bodies of these waggons are seven feet nine inches long, four feet five inches wide, and two feet four inches deep; and this sized waggon is calculated to contain the quantity of coal, or other matter, equivalent, with the waggon added to it, to make a weight altogether amounting to three tons and a quarter, as before stated, as the most eligible weight to move upon a cast-iron rail-road. In the Philosophical Magazine, July, 1811, are the following remarks concerning waggons, and also rail-roads, from which some idea may be formed of the utility of such roads. "The waggons on our cast-iron rail-roads, have not received the improvements of which they are capable; but with their present disadvantages, the following facts will evince the great saving of animal force to which rail-ways have given rise: "First, with a declivity of one and a quarter inch per yard, one horse takes downwards three waggons, each containing two tons: Second, in another place, with a rise of 1$\frac{6}{10}$th of an inch per yard, one horse takes two tons upwards. Third, with eight feet rise in 66 yards, which is nearly one-fourth of an inch per yard, one horse takes two tons upwards. Fourth, on the Penrhyn* railway, (same slope as above), two horses draw downwards four waggons, containing one ton of slate each. Fifth, with a slope of 55 feet per mile†, one horse takes from 12 to 15 tons downwards, and four tons upwards, and all the empty waggons. Sixth, at Ayr, one horse draws on a level five waggons, each containing one ton of coal. Seventh, on the Surrey rail-way,‡ one horse, on a declivity of one inch in 10 feet, is said to draw thirty quarters of wheat. From these cases, and the known laws of mechanics, we may perhaps safely infer, that where the apparatus is tolerably good, and well constructed, and the slope 10 feet per mile, two horses may draw five tons upwards, and seven tons downwards.

In cases in which inclined planes are to be had recourse to, to carry the rail-road over high ground, (and as there are several now passing such ridges,) the mode pursued in raising the waggons may not be unacceptable. The common plan is by a perpetual chain suspended at each end: it is so contrived, that the waggons disengage themselves the moment they arrive at the upper or lower extremity of the inclined plane. In some cases, the laden waggons descending, serve as a power to bring up the empty ones; but where there is an ascending as well as a descending traffic on the rail-way, steam-engines, water-wheels, or other machinery, to answer the same purpose, are used. "At Chapel le Frith there is an inclined plane of 550 yards. On the proposed rail from Glasgow to Berwick several inclined planes will be required, the summit of that rail-way being 753 feet above the level end of Berwick quay." As to the expense of rail-ways, they are inconsiderable, in comparison of canals. According to Mr. Fulton, "the cost of a single rail-road, with sufficient crossing places for a descending trade, was estimated at 1,600£. per mile." In Dr. Anderson's recreations, 1,000£. is mentioned as the estimate for a double one. However, Mr. Fulton's is most likely to be the nearest to accuracy, as his calculations were made from observation, and embraced the whole minutiæ of such a work.

The principal rail-ways in England and Wales, are, the Cardiff and Merthyn, 26¼ miles long, and runs near the Glamorganshire canal. The Caermarthen. The Sexhowry, 28 miles, in the counties of Monmouth and Brecknock. The Surrey, 26 miles. The Swansea, 7½ miles. One between Gloucester and Cheltenham. Besides several in the north of England.

* Plymley's Agricultural Report of Shropshire.

† Repertory, vol. iii.

‡ Malcolm's Agricultural Report of Surrey.

ENAMELLING.

ENAMELLING is the art of laying enamel on metals, as gold, silver, copper, &c., and of melting it at the fire, or of making divers curious works in it at a lamp. This art is of so great antiquity, as to render it difficult or impossible to trace it to its origin. It was evidently practised by the Egyptians, from the remains that have been observed on the ornamented envelopes of mummies. From Egypt it passed into Greece, and afterwards into Rome and its provinces, whence it was probably introduced into this country; as various Roman antiquities have been dug up in different parts of Britain, particularly in the Barrows, in which enamels have formed portions of the ornaments. The following are instances in proof of the antiquity of the art in this country: a jewel found at Athelney in Somersetshire, and now preserved at Oxford, bears witness to it, and by an inscription upon it, there is no doubt it was made by order of the great king Alfred. The gold cup, given by king John to the corporation of Lynn in Norfolk, proves that the art was known among the Normans, as the sides of the cup are embellished with various figures whose garments are partly composed of coloured enamels. The tomb of Edward the Confessor, in Westminster Abbey, built in the reign of Henry III., was ornamented with enamels; and a crosier of William of Wykeham, in the time of Edward III., exhibits curious specimens of the application of the art of enamelling.

Enamels are vitrifiable substances, and are usually arranged into three classes, viz. the transparent, the semi-transparent, and opaque. The basis of all kinds of enamel is a perfectly transparent and fusible glass, which is rendered either semi-transparent or opaque, by the admixture of metallic oxydes. M. Klaproth, some years ago, read to the Royal Academy of Sciences of Berlin, a very elaborate paper, the result of much research, "On the pastes, coloured glasses, and enamels of the ancients." From this we learn, that the art of colouring glass seems to be of nearly the same antiquity as the invention of making it; which is proved, not only from written documents, but likewise by the variously coloured glass corals with which several of the Egyptian mummies are decorated. This art supposes the possession of some chemical knowledge of the metallic oxydes, because these are the only substances capable, as far as we now know, of producing such an effect. Still a difficulty occurs: what were the means and processes employed by the ancients for this purpose? as they had no acquaintance with the mineral acids, which at present are usually employed in the preparation of metallic oxydes. It is, however, certain, that the art of giving many various colours to glass, must have obtained a considerable degree of perfection, as Pliny mentions the artificial imitation of the "Carbuncle," which was, at that time, a gem in the highest estimation. During the reign of Augustus, the Roman architects began to make use of coloured glass in their Mosaic decorations: thus it is known that an application of glass-pastes was resorted to, in a villa built by the emperor Tiberius on the island of Capri. Several specimens of this coming into the possession of Klaproth, were subjected, by that able chemist, to a chemical analysis; and he has detailed a very particular account of the several processes which he performed to ascertain the component parts of the different coloured glasses found in the ruins of the above-mentioned villa. His first attempt was upon the antique red glass, of which the colour is described as of a lively copper red. The mass was opaque, and very bright at the place of fracture; and of two hundred grains finely triturated, he found the constituent parts to be,

Silex	142	grains
Oxyde of Lead	28	
—— of Copper . . .	15	
—— of Iron	2	
Alumine	5	
Lime	3	
	195	
Loss	5	
	200	

On comparing the external characters of this red glass-paste with the cupreous scoriæ of a lively brown-red, such as is sometimes obtained on melting copper ores, M. Klaproth imagines that the ancients did not compound the above-mentioned paste directly from its constituent parts, but instead of them, employed, perhaps, copper scoriæ. And he adds, on this supposition, they had nothing more to do, than to select the best coloured pieces to fuse and cast them into plates.

In green glass, he found the constituent parts the same as in the red, but in different proportions. Both receive their colour from copper; and the reason why this metal produces in the one a red, and in the other

other a green colour depends on the different degrees of its oxygenation: it being an ascertained fact that copper in the state of a sub-oxyde, that is, only half saturated with oxygen, produces a reddish enamel, but when fully saturated with oxygen the enamel yielded is green.

M. Klaproth next analyzed the blue glass paste in which he found, next to the silex, that the oxyde of iron is the most predominating article. He expected to find that the colour had been given by cobalt, but could not discover the smallest trace of it, and therefore he infers that its blue colour entirely depends on the iron. This excited in him no surprise, knowing that iron, under certain circumstances, is capable of producing a blue enamel, as is clearly exhibited by the beautifully blue coloured scoriæ of iron, which are frequently met with in the highly heated furnaces on smelting iron stones. Our object in referring to these experiments is the fact that the coloured glass pastes of the ancients agree, in many respects, with modern enamels.

According to the writer in Dr. Rees's New Cyclopedia, white enamels are composed by melting the oxyde of tin with glass, and adding a small quantity of manganese to increase the brilliancy of the colour. The addition of oxyde of lead or antimony produces a yellow enamel: but a more beautiful yellow may be obtained from the oxyde of silver. Reds are formed by an intermixture of the oxydes of gold and iron, that composed by the former being the most beautiful and permanent. Greens, violets, and blues are formed from the oxydes of copper, cobalt and iron; and these, when intermixed in different proportions, afford a great variety of intermediate colours. Sometimes the oxydes are mixed before they are united to the vitreous bases. Such are, according to this author, the principal ingredients employed in the production of various enamels; but the proportions in which they are used, as well as the degree and continuance of the heat necessary to their perfection constitute the secrets of the art. Besides these, there are probably other substances occasionally used in the composition of enamels, and it has been asserted that the peculiar quality of the best kinds of Venetian enamel, is owing to the admixture of a particular substance found on Mount Vesuvius, and ascertained to be thrown up by that volcano.

Enamels, as we have seen, are commonly laid upon a metal ground; they are, however, sometimes used in substance for dishes, flower-pots, and ornamented vessels of different kinds. In these cases the enamel is run into moulds, immediately from the pots in which it has been melted. The metals employed in this business are gold, silver, and copper; of the others some are too *fusible* to endure the action of the fire, and others, as platina, &c. are too *strong* for the enamel; that is, the adhesion between the two substances is not sufficiently powerful to keep them together, the enamel cracking as it grows cold, and flying off in flakes. Hence it is inferred that a certain, though perhaps very slight degree of oxydation is necessary to make the enamel and the metal unite with firmness. Gold is the best substance for enamelling upon because its richness of colour exhibits a beautiful tinge through the enamel, but on account of its price copper is most used.

Enamelling in this country is by custom divided into two branches, viz. dial-plate enamelling, and transparent enamelling. The former includes the manufacture of clock and watch plates: the latter comprehends the enamelling of watch cases, and other articles of jewellery.

Dial-plate enamelling is divided into two parts or branches, viz. the *hard* and the *soft*: in the first branch the Venetian enamels only are employed, which if genuine are made at Venice, but from the operations of war are now very difficult to be obtained, and what used to fetch only two or three shillings per lb. are not to be had for twice as many pounds. In soft enamelling the English or glass enamels are used.

In preparing the metal to be enamelled on, the process is the same whether it be gold, silver or copper. To take copper, as an example, in the manufacture of watch-dials. The copper being evenly flatted in long slips and brought to a proper degree of thickness, pieces are cut off for use, according to the size wanted. They are then annealed, to give them the pliability requisite for receiving the dies. The dies are intended to bring the plates into the proper form; and to punch the eye or eyes out, according as the watch is intended only to exhibit the minutes; or minutes and seconds, &c. When these are made, the plates are ready to have the feet soldered on, by which it is to be pinned down to the brass edge or frame of the watch. The feet are always of wire of the same kind of metal as that to be enamelled upon, and they are fastened to the copper by means of speltre, or of silver solder. When the legs are soldered on, the plates should be thrown into the pickling pan, as it is called, to free them from the scale or oxydable covering acquired by the heat communicated during the operation of soldering. The pickle is a solution of sulphuric or nitric acid. When the scales of oxyde are removed the plates are fit for enamelling.

The enamel as it comes from the makers is generally in small cakes from four to five inches in diameter. This is finely triturated, but the exact point at which trituration should be discontinued can only be ascertained by experience, as the different kinds of enamels, and the several modes of application, require the ground enamel to be either more or less fine. In this process many coppers are usually prepared to go on with at once, in order to save time, materials and labour. When the enamel is ground, the coppers having been first cleansed by the pickle, and carefully brushed out with water, are spread with their faces downwards on a smooth napkin, and a thin layer of hard enamel, called, in its ground state, the backing, is spread over the under sides with the end of a quill or with a small bone spoon. The coppers are then slightly pressed on by another soft cloth or napkin, which by imbibing some portion of the water, renders the

the enamel dry enough to be smoothly and evenly spread with the rounded side of a steel spatula. This operation is to be repeated till the back becomes completely smooth, and the enamel is of an equal thickness all over. When it is properly spread and the loose particles are cleared away from the edge and eyes of the coppers, the process of "laying the bottoms" is finished. The next operation is to lay the *first coats*; that is, to spread a layer of glass enamel over the upper sides of the coppers. In doing this, great care must be taken to remove any dirt or extraneous particles of enamel, as the mixture of any hard enamel with the glass would infallibly spoil the work. The glass is then spread upon the copper in a layer, and when the water is taken up, the first coats are placed upon rings for firing. The rings used in enamelling are made of a mixture of pipe-makers and Stourbridge clay rolled up in the form of cylinders, and turned in a lathe by means of a cylindrical piece of wood forced through the centre of the mass while it is wet. Each ring is made on the upper side slightly concave, and the under side is nearly flat. Through the concavity thus given to the rings, the edge of the copper or dial plate only is suffered to touch, by means of which the enamel on the back remains undisturbed, and the edges are prevented from sticking by rubbing over the surfaces of the rings with soft chalk or whiting. The first coats having been carefully placed on, the rings are next put into a shallow tin vessel, and the moisture slowly evaporated from the enamel by a moderate heat; for if the evaporation be too quick, the work will be in danger of being spoilt by blisters; these are small air bubbles, which by rising to the surface of the dial plates, destroy their smoothness and beauty. The "firing" is executed beneath a muffle, placed in a small furnace ignited with coke and charcoal. The proper degree of heat being given the enamel melts, and becoming in a short time properly consolidated, the first coat is complete. The enamel must not be over-fired, as in that case the glass would lose some portion of its opacity, independently of other defects that might be detrimental to the work. As all solids when reduced to a granulated state occupy a greater space than before, it will be found that a very considerable depression has been produced in the enamel of the first coats by the act of fusion, and that the edges and eyes of the plates are now much above the surface. This deficiency in substance it is the business of the "second coats" to supply, which are given in the same manner as that already described. The second firing requires an equally cautious management as the former. The plates must not be over fired, nor must the enamel be suffered to melt too rapidly, but a kind of rotatory motion called *coddling* must be given to the work till the fusion be complete; a proper knowledge of which can only be gained by practice. The work is now fit for *polishing*, which term not only means to render bright according to the usual acceptation of the word, but also to make even without any reference to glossiness. The enamel has a natural brightness of surface acquired from the fire; and when this is removed, it is only necessary again to expose it to a due heat to cause it to re-assume its former character. Yet as this brightness exists independently of evenness, and as evenness is essential to the perfection of enamelling, it is requisite in most cases to produce that quality by polishing.

The materials used in polishing glass plates are grey-stones, rag-stones, sometimes called burrs, fine-ground silver-sand and water. In this operation, great care must be taken that the pressure be not too powerful, as the plates will in that case crack in the fire, and can never be properly mended. When the enamel is sufficiently polished, which is known by the criterion of all the gloss being removed, the plates must be clean washed, and the specks of dirt picked out with a sharp graver; and being wiped dry are again placed upon the rings for firing. When the surface is properly run and become smooth, even and bright, the plate is completed, and when cold it is fit for painting on.

For more common work there are two other modes practised; these are called "run-down plates" and "run-down second coats." The former are those which are made by laying the enamel upon the coppers in sufficient quantity to form plates of the required thickness, without putting on a second coat. Both labour and fire are thus saved, but that neatness and regularity which are acquired by the first method are rarely attainable in this. Of course only the most common work can be thus manufactured. There is a superior method to this made use of, viz. "the run-down one-coats," which are polished off with rag-stone and undergo a second firing. The "run-down second coats" are those which are reduced to a surface comparatively even by a second fire.

"In enamelling *hard plates*" says the writer already referred to, "for watches, the coppers and the first coats are prepared in the manner already described, excepting that the layer of glass is rather thinner than in glass-work only. The hard enamel is broken down and ground in the same way as the glass, if a small quantity alone be wanted; but if otherwise, it is first broken from the cake with a hammer, and then pounded in a steel mortar till reduced to coarse grains. These grains are then exposed to the action of a magnet, in order that all the particles of steel that have been broken off the mortar in the act of pounding may be taken away, as they would infallibly spoil the work by rising in black specks to the surface of the enamel when in the fire. As an additional precaution, it is also necessary to put the granulated enamel into a small bason, and pouring upon it a strong solution of sulphuric or nitrous acid, to suffer it to stand some hours that the steel particles may be wholly dissolved, after which the enamel is to be carefully washed till the water comes off pure and tasteless. The enamel is then ground to the necessary fineness in an agate mortar, and afterwards spread over the first coat with a quill in small quantities, and as evenly as it can be laid. The water is then partly absorbed by a fine clean napkin, and the enamel smoothly spread

spread and closely compressed with the spatula, after which more water is absorbed, and the spreading is continued till the surface lies even. The plate is then put upon a ring, and properly fired; and it is afterwards polished by placing it upon a cork, the top edge being taken off with a fine grey-stone, and wearing away the surface, first, by a very fine-grained Lancashire file, or smooth piece of steel, and silver-sand, ground to an almost impalpable powder; secondly, by a fine blue-stone and sand; and, thirdly, by the blue-stone alone. With the latter, a sort of half polish should be given the enamel, and the nigher that polish approaches to complete glossiness the better, as the plate will then be finished by a third fire with a less degree of heat than would be otherwise wanted. In this process, much caution is required to prevent scratches which cannot be *run up* by the fire, without giving the enamel a greater degree of heat than it will bear. When the polishing is completed, the plate is carefully cleaned with ground enamel; and if there should be any specks, they must be picked out with a small and sharp diamond, and the hollows very dexterously filled up with enamel, that they may neither rise above nor sink below the common surface, when the plate is again fired. Hard enamel dials are always considerably more costly than glass ones, owing to the greater labour and attention that are requisite in making them; and the best watches are almost always made up with dials of this kind."

The operations of "transparent enamelling" are nearly similar to those that have been already described in the manufacture of watch dials. But as the work is generally of a more minute kind, greater delicacy of handling is required. Watch cases are usually enamelled on gold, as well as the superior articles of the fancy kind; and the surface of the gold is frequently engraved into different figures and compartments, before the enamel is laid on; hence the work has a beautiful variegated appearance through the enamelled coating.

In ornamental transparent work, a good effect is produced by applying small and very thin pieces of gold or silver, cut or stamped into different figures, as acorns, oak-leaves, vine-leaves, bunches of grapes, fruits, &c., upon the surface of the first coating of enamel, where they are fixed by fire, and are afterwards covered over by the second, through which they make a beautiful appearance.

Such are the mechanical operations: we shall now proceed to consider the nature and composition of enamels. The exact composition of the opaque *white* enamel is a matter of considerable importance in this trade: it should be of a very clear fine white, so nearly opaque as only to be translucent at the edges, and at a moderate red heat it should run into a kind of paste or imperfect fusion, which allows it to extend itself freely and uniformly, and to acquire a glossy even surface, without fully running into a thin glass. The opaque white of this enamel is given by the oxyde of tin, which possesses, even in a very small proportion, the property of rendering vitrescent mixtures white and opaque, or milky, and when otherwise coloured, opalascent. The oxyde of tin is always mixed with three or four times its quantity of oxyde of lead, and it appears necessary that the metals should be previously mixed by melting, and the alloy then calcined; but on this subject, and on others of a similar nature, we shall give the directions of M. Clouet, taken from the 34th vol. of the Annales de Chemie.

White enamel, either for earthen-ware, or the purpose of being applied on metals, is composed in the following manner: You first calcine a mixture of lead and tin, which may be varied in the following proportions, viz. for 100 parts of lead, 15, 20, 30, and even 40 of tin. A mixture of lead and tin calcines very easily in contact with the air. As soon as this mixture is brought to a red heat, nearly a cherry colour, it burns like charcoal, and is calcined speedily. The composition which calcines best, is that which in 100 pounds of lead contains from 20 to 25 of tin. The tin, here meant, is pure tin. In proportion as the calcination is effected, you must take out the calcined part, and continue to oxydate the rest, until the whole has become pulverulent. As some small particles always escape calcination, you must expose to the fire a second time the oxyde obtained, in order to calcine it completely; which may be easily known by its ceasing to sparkle; that is to say, when you no longer see any parts burn like coal, and when the whole appears of an uniform colour. When the proportion of tin exceeds 25 or 30, a stronger fire is necessary to produce calcination. In a word, by varying the degrees of heat, you will be able to discover that best suited to the mixture on which you operate. A hundred parts of the calx above-mentioned, which in the French potteries is called calcine, is generally taken with 100 parts of sand. From 25 to 36 pounds of sea-salt, or muriate of soda, are added: the whole is well mixed together, and it is fused in the bottom of a furnace in which potter's ware is baked. This matter is generally placed on sand, on lime quenched in the open air, or on ashes. The bottom of the mass is in general badly fused. This, however, does not prevent the matter, after it has been pounded, and applied on the articles, from becoming exceedingly white and hard in the furnace. When taken from the furnace, it is not white; it is even often very black: in general it is marbled with black, grey, and white. This process is that generally used in potteries. In the composition destined for earthen-ware, the proportion of 25 parts of tin to 100 of lead is never exceeded: for common earthen-ware, the manufacturers are even satisfied with 15 of tin to 100 of lead. It may be easily seen, that if you wish to obtain an enamel whiter and more fusible, you must diminish the quantity of sand; but there is no necessity for augmenting that of the sea-salt, or muriate of soda; as the whiteness and opacity depend on the quantity of tin, calcine may be used, which contains 25 or 30 per cent. For example, 100 of such calcine, 60 of sand, and 25 of marine salt,

salt, give a composition exceedingly fusible. But it is to be observed, that it is necessary to employ some further manipulations when you wish to have enamel proper for being applied on metal, and are desirous to give it all the perfection of which it is susceptible. In that case, you do not employ crude sand, but calcine it in a strong heat, with a quarter of its weight of marine salt, either in a small quantity in a crucible, or on a large scale in a potter's furnace. If you wish to have a very fusible enamel, you may even add minium, or lead calcined by the former operation, and nearly as much sea-salt, that is to say, a fourth. You then obtain a white mass, half fused and porous, which you pulverise, and employ in the composition of enamel instead of sand, and in the same proportions as sand: you may diminish the quantity of this matter to 50 per cent., if you are desirous to obtain an enamel very fusible. This will depend also on the calcine employed; for that which is most charged with tin is the least fusible. When you wish to have fluxes for the colours, you employ the same compositions before mentioned, except that you put little or no tin into the lead. In the latter case you must generally employ minium. This flux is good for certain colours, but not for all. There are some which become tarnished by fluxes, that contain the oxydes of lead. In that case, you must make fluxes without oxyde of lead. Nitre and borax are generally used for making this glass, but without oxyde of tin.

The following are those which M. Clouet has tried: Three parts of siliceous sand, one of chalk, and three of calcined borax, give a matter proper to be used as a flux for purples, blues, and other delicate colours. Three parts of white or flint glass, one of calcined borax, a quarter of a part of nitre, one of the white oxyde of antimony made with nitre well washed, give an exceedingly white enamel, which may serve also as a flux for purple, and particularly for blue. Sixty parts of enamel sand or less, thirty of alum, thirty-five of sea-salt, and a hundred of minium, or any other oxyde of lead, give a white enamel when the fluxes do not predominate too much, and a gelatinous glass when a great deal of flux has been added. This glass is good for red, and the enamel may be applied to all kinds of clay capable of sustaining a strong heat. It is of great importance to remark, and to know, that the sand employed for enamel must not be sand which contains only silex; sand of that kind alone is of no use. The sand proper for this purpose is that which contains talc with silex. To make a sand proper for enamel, and the fluxes of colours, &c., there must be nearly one part of talc, and three of siliceous sand. What appears most essential in regard to the success of enamel, is the choice of sand. It is very possible to compose this sand by art; and though (says M. Clouet) I have not decomposed it, I have found by synthesis, that three parts of siliceous sand and one of talc, form an excellent sand for enamel. From this it may be readily seen, that to compose with facility sand for enamel, nothing is necessary but to determine, by a good analysis, the quantity of talc. This sand may be procured in places where earthen-ware is made. It may be easily known; for, besides the siliceous sand, which forms the greatest part of it, you may observe in it talcy particles in great abundance; and to be good, it must contain nearly a quarter. When it does not contain a sufficient quantity, the enamel it produces fuses with more difficulty, and does not become smooth; it remains granulated and pitted. There are certainly some combinations of earth which may produce very good fluxes, either for enamel or for transparent colours. It might be attended with advantage to try some of these combinations. Ponderous earth (barytes) and lime fuse very well together: by adding a little silex, or a little magnesia, it is probable that an excellent matter might be produced. If this glass, composed of lime and barytes only, had sufficient solidity to resist the air and weak acids, there would be no necessity, perhaps, to add silex; but if the marine salt ought to enter into the composition of this kind of glass, it should seem, that silex ought likewise to form a part of it. The experiments on this head, for the sake of trial, may be varied different ways. When the glass destined to serve as flux for colours is employed, it is customary, in order that they may be rendered more fusible, to add a little nitre and borax. The common borax of the shops contains an excess of soda, which it would probably be of benefit to saturate with the nitric acid, or the flux might be re-baked with the dose of nitre and borax, or of nitric borax, which might be added before being employed. It is only to colours, such as purple and the oxyde of cobalt, that nitre and borax are added.

Our chemist tried to find a substitute for marine salt, in the composition of white enamel. Potash produced only an ugly and ill fused grey mass, which acquired no lustre in the furnace; nitre produced a green mass, but exceedingly friable; sulphate of potash produced very nearly the same effect, only the mass was a little whiter; but neither of these enamels was worth any thing. Pure soda was not tried, but common soda has been extolled; as, however, it contains a great deal of marine salt, it must undoubtedly be on account of this salt that it produces a good effect. Pure soda may nevertheless be tried, either alone or with marine salt; it perhaps might produce no bad effect with potash. A mixture of equal parts of lime and argil has been tried, to which was added one part of silex, and likewise without silex; but this mixture did not supply the place of talcky sand. This sand is not in general found in grains; it exhibits itself most commonly under the form of a stone, such as free-stone; but some of it is found also in grains. We should be much deceived in making white enamel, were we to employ the oxydes of tin and lead separately. None of the authors who have treated on pottery say what they ought respecting enamel, nor even respecting the composition or nature of the earth proper for bearing an enamel. It is essential that the lead and tin for making the oxyde destined to produce white enamel,

enamel, should be fused and mixed together before they are calcined; and if it be wished that the enamel should immediately acquire its full whiteness, it will be requisite that the calcination should be complete. Bismuth might perhaps be employed as a substitute for the lead, and it is not improbable that it would give a good product. Bismuth also might be mixed with the lead in the following manner, viz. one part of lead, one of bismuth, and one of tin: or other proportions might be employed. As the oxyde of bismuth, however, is exceedingly fusible, it might probably be admitted, with great advantage, into certain fluxes. A mixture of lead and tin, detonated with nitre, would be useful. Though the white calx of regulus of antimony made by nitre and well washed, produces a very beautiful white enamel when fused with three parts of white glass, which contains neither lead nor other metallic oxydes, and one of glass of borax, with a half or fourth part of nitre; yet this calx, so white when mixed with the composition of enamel, made with enamel sand, and the combined oxyde of lead and tin, instead of increasing, tarnishes the whiteness, and only gives a bluish enamel of a livid colour. Perhaps enamels, completely made and mixed together in the first instance, would not produce the same effect. I have, however, (says M. Clouet,) employed this composition as a flux for colours, which, applied afterwards on the enamel of earthen-ware, preserved its beauty. I put some of this pure enamel also over that of earthen-ware, and I think it preserved its whiteness.

The principal quality of good enamel, and that which renders it fit for being applied on baked earthen-ware, or on metals, is the facility with which it acquires lustre by a moderate heat, a cherry-red heat, more or less, according to the nature of the enamel, without entering into complete fusion. Enamels applied to earthen-ware and metals possess this quality. They do not enter into complete fusion; they assume only the state of paste, but of a paste exceedingly firm; and yet when baked, one might say that they had been completely fused. There are two methods of painting on enamel: on raw or on baked enamel. Both these methods are employed, or may be employed, for the same object. Solid colours, capable of sustaining the fire necessary for baking the enamel ground, may be applied in the form of fused enamel on that which is raw, and the artist may afterwards finish with the tender colours. The colours applied on the raw material do not require any flux; there is one, even, to which silex must be added, that is, the calx of copper, which gives a very beautiful green; but when you wish to employ it on the raw material, you must mix with it about two parts of its weight of silex, and bring the mixture into combination by means of heat. You afterwards pulverise the mass you have thus obtained, in order to employ it. To obtain good white enamel, it is of great importance that the lead and tin should be very pure. If these metals contain copper or antimony, as is often the case, the ename will not be beautiful. Iron is the least hurtful.

Of Coloured Enamels.—All the colours may be produced by the metallic oxydes. These colours are more or less fused in the fire, according as they adhere with more or less strength to their oxygen. All metals which readily lose their oxygen cannot endure a great degree of heat, and are unfit for being employed on the raw material.

Purple.—This colour is the oxyde of gold, which may be prepared different ways, as by precipitating, by means of a muriatic solution of tin, a nitro-muriatic solution of gold much diluted in water. The least quantity possible of the solution of tin will be sufficient to form this precipitate. The solution of tin must be added gradually until you observe the purple colour begin to appear: you then stop, and having suffered the colour to be deposited, you put it into an earthen vessel to dry slowly. The different solutions of gold, in whatever manner precipitated, provided the gold is precipitated in the state of an oxyde, give always a purple colour, which will be more beautiful in proportion to the purity of the oxyde, but neither the copper nor silver with which gold is generally found alloyed, injure this colour in a sensible manner: it is changed, however, by iron. The gold precipitate which gives the most beautiful purple, is certainly fulminating gold, which loses that property when mixed with fluxes. Purple is an abundant colour; it is capable of bearing a great deal of flux, and in a small quantity communicates its colour to a great deal of matter. It appears that saline fluxes are better suited to it than those in which there are metallic calces. Those, therefore, which have been made with silex, chalk, and borax, or white glass, borax, and a little white oxyde of antimony, with a little nitre, as I have already mentioned, ought to be employed with it. Purple will bear from four to twenty parts of flux, and even more, according to the shade required. Painters in enamel employ generally for purple a flux which they call brilliant white. This flux appears to be a semi-opaque enamel, which has been drawn into tubes, and afterwards blown into a ball at an enameller's lamp. These bulbs are afterwards broken in such a manner, that the flux is found in small scales, which appear like the fragments of small hollow spheres. Enamel painters mix this flux with a little nitre and borax. This matter, which produces a very good effect, I employed, without attempting to decompose it. It may be a very fusible common white enamel which has been blown into that form. It is to be remarked, that purple will not bear a strong heat; and the colour is always more beautiful if the precipitate is ground with the flux before it has become dry.

Red.—We have no metallic oxyde capable of giving directly a fused red; that is to say, we have no metallic calces which, entering into fusion, and combining, under the form of transparent glass, with fluxes or glass, give directly a red colour. To obtain this colour, it must be compounded different ways, as follows:—Take two parts, or two parts and a half (you may, however, take only one part,) of sulphate of iron and of sulphate of alumine, fuse them together in their water of crystallization,

lisation, and take care to mix them well together. Continue to heat them, to complete dryness; then increase the fire so as to bring the mixture to a red heat. The last operation must be performed in a reverberating furnace. Keep the mixture red until it has every where assumed a beautiful red colour, which you may ascertain by taking out a little of it from time to time, and suffering it to cool in the air. You may then see whether the matter is sufficiently red: to judge of this, it must be left to cool, because while hot it appears black. The red oxydes of iron give a red colour; but this colour is exceedingly fugitive; for, as soon as the oxyde of iron enters into fusion, the portion of oxygen which gives it its red colour leaves it, and it becomes black, yellow, or greenish. To preserve, therefore, the red colour of this oxyde in the fire, it must be prevented from vitrifying, and abandoning its oxygen. I have tried (says M. Clouet,) a variety of different substances to give it this fixity, but none of them succeeded except alum. The doses of alum and sulphate of iron may be varied. The more alum you add, the paler will be the colour. Three parts of alum to one of sulphate of iron give a colour which approaches a flesh colour. It is alum also which gives this colour the property of becoming fixed at a very strong heat. This colour may be employed on raw enamel; it has much more fixity than the purple, but not so much as the blue of cobalt. It may be washed to carry off the superfluous saline matter, but it may be employed also without edulcoration; in that state it is even more fixed, and more beautiful. It does not require much flux; the flux which appeared to me to be best suited to it, is composed of alum, minium, marine salt, and enamel sand. This flux must be compounded in such a manner as to render it sufficiently fusible for its object: from two to three parts of it are mixed with the colour. In general, three parts of flux are used for one of colour; but this dose may and ought to be varied according to the nature of the colour and the shade of it required. Red calx of iron alone, when it enters into fusion with glass, gives a colour which seems to be black; but if the colour be diluted with a sufficient quantity of glass, it at last becomes of a transparent yellow. Thus, the colour really produced by calx of iron combined with glass is a yellow colour, but which being accumulated, becomes so dark, that it appears black. In the process above given for making the red colour, the oxyde of iron does not fuse; and this is the essential point; for if this colour is carried in the fire to vitrification, it becomes black, or yellowish, and disappears if the coat be thin, and the oxyde of iron present be only in a small quantity.

Yellow.—Though yellow may be obtained in a direct manner, compound yellows are preferred, because they are more certain in their effect, and more easily applied, than the yellow which may be directly obtained from silver. The compound yellows are obtained in consequence of the same principles as the red colour of iron. For this purpose we employ metallic oxydes, the vitrification of which must be prevented by mixing with them other substances, such as refractory earths, or metallic oxydes difficult to be fused. The metallic calces which form the bases of the yellow colours are generally those of lead; as minium, the white calx of lead, or litharge, the white calx of antimony, called diaphoretic antimony; that called "crocus metallorum" is also employed. This regulus, pulverised, and mixed with white oxyde, gives likewise a yellow. The following are the different compositions used: one part of the white oxyde of antimony, one of the white oxyde of lead (or two or three); these doses are exceedingly variable; one part of alum, and one of sal-ammoniac. When these matters have been all pulverised, and mixed well together, they are put in a vessel over a fire sufficient to sublimate and decompose the sal-ammoniac; and when the matter has assumed a yellow colour, the operation is finished. The calces of lead mixed in a small quantity either with silex or alumine, also with the pure calx of tin, exceedingly white, give likewise yellows. One part of the oxyde of lead is added to two, three, or four of the other substances above-mentioned. In these different compositions for yellow, you may use also oxyde of iron, either pure, or that kind which has been prepared with alum and vitriol of iron: you will then obtain different shades of yellow. From what has been said, you may vary these compositions of yellow as much as you please. Yellows require so little flux, that one or two parts, in general, to one of the colour, are sufficient. Saline fluxes are improper for them, and especially those which contain nitre. They must be used with fluxes composed of enamel sand, oxyde of lead, and borax, without marine salt. A yellow may be obtained also directly from silver. All these mixtures may be varied, and you may try others. For this purpose you may use sulphate of silver, or any oxyde of that metal mixed with alumine or silex, or even with both, in equal quantities. The whole must be gently heated until the yellow colour appears, and the matter is to be employed with the fluxes pointed out for yellows. Yellow of silver, like purple, cannot endure a strong heat: a nitric solution of silver may be precipitated by the ammoniacal phosphate of soda, and you will obtain a yellow precipitate, which may be used to paint in that colour with fluxes, which ought then to be a little harder. Besides the methods above-mentioned, the best manner of employing the oxyde of silver is, in my opinion, to employ it pure: in that case, you do not paint, but stain. It will be sufficient, then, to lay a light coating on the place which you wish to stain yellow, and to heat the article gently to give it the colour. You must not employ too strong a heat: the degree will easily be found by practice. When the article has been sufficiently heated, you take it from the fire and separate the coating of oxyde, which will be found reduced to a regulus. You will then observe the place which it occupied tinged of a beautiful yellow colour, without thickness. It is chiefly on transparent glass that this process succeeds best. Very fine

fine silver filings produce the same effect: but what seemed to succeed best in this case was sulphate of silver well ground up with a little water, that it may be extended very smooth. From what has been said, it may readily be seen that this yellow must not be employed like other colours; that it must not be applied till the rest have been fused; for, as it is exceedingly fusible, and ready to change, it would be injured by the other colours; and as the coating of silver which is reduced must be removed the fluxes would fix it, and prevent the possibility of its being afterwards separated. Working on glass is not attended with this inconvenience, because the silver-yellow is applied on the opposite side to that on which the other colours are laid.

GREEN.—Green is obtained directly from the oxyde of copper. All the oxydes of copper are good; they require little flux, which even must not be too fusible: one part or two of flux will be sufficient for one oxyde. This colour agrees with all the fluxes, the saline as well as the metallic, which tends to vary a little the shades. A mixture of yellow and blue is also used to produce green. Those who paint figures or portraits employ glass composed in this manner; but those who paint glazed vessels, either earthen-ware or porcelain, employ in general copper green. Independently of the beautiful green colour produced by oxydated copper, it produces also a very beautiful red colour. This beautiful red colour, produced by copper, is exceedingly fugitive. The oxyde of copper gives red only when it contains very little oxygen, and approaches near to the state of a regulus. Notwithstanding the difficulty of employing this oxyde for a red colour, a method has been found to stain transparent glass with different shades of a very beautiful red colour by means of calx of copper. The process is as follows: you do not employ the calx of copper pure, but add to it calx of iron, which for that purpose must not be too much calcined; you add also a very small quantity of calx of copper to the mass of glass which you are desirous of tinging. The glass at first must have only a very slight tinge of green, inclining to yellow. When the glass has that colour you make it pass to red, and even a very dark red, by mixing with it red tartar in powder, or even tallow. You must mix this matter well in the glass, and it will assume a very dark red colour. The glass swells up very much by this addition. Before it is worked it must be suffered to settle, and become compact; but as soon as it has fully assumed the colour it must be immediately worked, for the colour does not remain long, and even often disappears while working; but it may be restored by heating the glass at the flame of a lamp. It is difficult to make this colour well; but when it succeeds it is very beautiful, and has a great deal of splendour. By employing the calx of copper alone for the processes above mentioned, you will obtain, when you succeed well, a red similar to the most beautiful carmine. The calx of iron changes the red into vermilion, according to the quantity added. If we had certain processes for the making this colour, we should obtain all the shades of red from pure red to orange, by using, in different proportions, the oxyde of copper and that of iron. The calx of copper fuses argil more easily than silex: the case is the same with calx of iron. If you fuse two or three parts of argil with one of the oxyde of copper, and if the heat be sufficient, you will obtain a very opake enamel, and of a vermilion red colour: the oxyde of copper passes from red to green through yellow, so that the enamel of copper, which becomes red at a strong heat, may be yellow with a weaker heat. The same effect may be produced by de-oxydating copper in different degrees: this will be effected according as the heat is more or less violent. The above composition might, I think, be employed to give a vermilion red colour to porcelain. The heat of the porcelain furnace ought to be of sufficient strength to produce the proper effect. The calx of iron fused also with argil, in the same proportions as the calx of copper, gives a very beautiful black. These proportions may, however, be varied.

BLUE.—Blue is obtained from the oxyde of cobalt. It is the most fixed of all colours, and becomes equally beautiful with a weak as with a strong heat. The blue produced by cobalt is more beautiful the purer it is, and the more it is oxydated. Arsenic does not hurt it. The saline fluxes which contain nitre are those best suited to it: you add a little also when you employ that flux which contains a little calcined borax or glass of borax, though you may employ it also with that flux alone. But the flux which, according to my experiments, gives to cobalt-blue the greatest splendour and beauty is that composed of white glass (which contains no metallic calx) of borax, nitre, and diaphoretic antimony well washed. When this glass is made for the purpose of being employed as a flux for blue, you may add less of the white oxyde of antimony: a sixth of the whole will be sufficient.

VIOLET.—Black calx of manganese, employed with saline fluxes, gives a very beautiful violet. By varying the fluxes, the shade of the colour may also be varied: it is very fixed as long as it retains its oxygen. The oxyde of manganese may produce different colours; but for that purpose it will be necessary that we should be able to fix its oxygen in it in different proportions. How to effect this has perhaps never yet been discovered. These are all the colours obtained from metals. From this it is evident that something still remains to be discovered. We do not know what might be produced by the oxydes of platina, tungsten, molybdena, and nickel: all these oxydes are still to be tried; each of them must produce a colour, and perhaps red, which is obtained neither directly nor with facility from any of the metallic substances formerly known and hitherto employed.

Having laid before the English artist the result of M. Clouet's Researches, as they were presented to the French National Institute, of which he was an associate; we shall add a few general observations taken from those of our own countrymen who have made the subject

ject of enamelling their study and employment. The most beautiful and expensive colour known in this branch of the art is an exquisitely fine rich and purplish tinge, given by the salts and oxydes of gold, especially the purple precipitate formed by tin in one form or other, and the nitro-muriate of gold, and also by fulminating gold. This fine colour, however, requires much skill in the artist to be fully brought out. Other and commoner reds are given by the oxyde of iron, but this requires the mixture of alumine, or some other substance refractory in the fire, otherwise what would under proper circumstances be a full red will degenerate into a black.

Yellow is either given by the oxyde of silver alone, or by the oxydes of lead and antimony, with similar mixtures to those required for iron. The silver is as tender a colour as gold, and as readily injured or lost in a high heat. Green is given by the oxyde of copper, or it may also be produced by a mixture of yellow colours. Blue is given by cobalt, and this seems the most certain of all enamel colours, and as easy to be managed. Black is produced by a mixture of cobalt and manganese. "The reader," says Mr. Aikin, in his Chemical Dictionary, "may conceive how much the difficulties of this nice art are increased, when the object is not merely to lay an uniform coloured glazing on a metallic surface, but also to paint that surface with figures and other designs that require extreme delicacy of outline, accuracy of shading, and selection of colouring. The enamel painter has to work not with actual colours, but with mixtures which he knows from experience will produce certain colours after the operation of the fire, and to the common skill of the painter in the arrangement of his pallet and the choice of his colours; the enameller has to add an infinite quantity of practical knowledge of the chemical operation of one metallic oxyde on another, the fusibility of his materials, and the utmost degree of heat at which they will retain not only the accuracy of the figures which he has given, but the precise shade of colour which he intends to lay on. Painting in enamel requires a succession of firings; first, of the ground which is to receive the design, and which itself requires two firings, and then of the different parts of the design itself. The ground is laid on in the same general way as the common watch face enamelling already described. The colours are the different metallic oxydes melted with some or other vitrescent mixture, and ground to extreme fineness. These are worked up with an essential oil, that of spike is preferred, and next to it the oil of lavender, to the proper consistence of oil colours, and are laid on with a very fine hair brush. The essential oil should be very pure, and the use of this rather than any fixed oil, is probably that the whole may evaporate completely in a moderate heat, and leave no carbonaceous matter in contact with the colour when red-hot, which might affect its degree of oxydation, and thence the shade of colour which it is intended to produce. As the colour of some of the vitrified metallic oxydes, such as that of gold, will stand only at a moderate heat, while others will bear and even require a higher temperature to be properly fixed, it forms a great part of the technical skill of the artist to apply different colours in their proper order; fixing first those shades which are produced by the colours that will endure the highest degree of heat, and finishing with those that demand the least heat. The outline of the design is first traced on the enamel, ground and burnt in; after which the parts are filled up gradually with repeated burnings to the last and finest touches of the tenderest enamel."

Those who paint on enamel, on earthen-ware, porcelain, &c., must regulate the fusibility of the colours by the most tender of those employed, as, for example, the purple. When the degree which is best suited to purple has been found, the other less fusible colours may be so regulated (by additions of flux), when it is necessary to fuse all the colours at the same time, and at the same degree of heat. You may paint also in enamel without flux; but all the colours do not equally stand the heat which must be employed. If the enamel, however, on which you paint be very fusible, they may all penetrate it. This manner of painting gives no thickness of colour; on the contrary, the colours sink into the enamel at the places where the tints are strongest. To make them penetrate and give them lustre, a pretty strong fire will be necessary to soften the enamel and bring it to a state of fusion. This method cannot be practised but on enamel composed with sand, which I call enamel-sand, as already mentioned. It may be readily seen, also, that the colours and enamel, capable of enduring the greatest heat, will be the most solid, and the least liable to be changed by the air. On this subject we shall have occasion to enlarge under the articles Glass and Porcelain *Manufactures*.

The following method of filling up engraving on silver with a durable black enamel is practised in Persia and India.

They take half an ounce of silver, two ounces and a half of copper, three ounces and a half of lead, twelve ounces of sulphur, two ounces and a half of sal-ammoniac. The metals are melted together and poured into a crucible, which has been before filled with pulverised sulphur made into a paste by means of water; the crucible is then immediately covered that the sulphur may not take fire, and this regulus is calcined over a smelting fire until the superfluous sulphur be burned away. This regulus is then coarsely pounded, and with a solution of sal ammoniac formed into a paste, which is rubbed into the engraving on silver plate. The silver is then wiped clean, and suffered to become so hot under the muffle, that the substance rubbed into the strokes of the engraving melts and adheres to the metal. The silver is afterwards wetted with the solution of sal-ammoniac, and again placed under the muffle till it becomes red hot. The engraved surface may then be smoothed and polished without any danger of the black substance, which is an artificial kind of silver ore, either dropping out or decaying. In this manner is all the silver plate brought from Russia ornamented with black engraved figures.

ENGRAVING.

The art of engraving, in England, has gradually arisen to its present advanced state from the rude mechanical practice by our British ancestors. That it was practised in this island from a very early period, may be seen by the remains of the instruments of war, and other antiquities, which have been found in the Celtic and Saxon tumuli: these frequently bear the marks of the graver, or of some tool very similar to it; and the numerous coins of antiquity must satisfy every inquirer of the early British existence of this species of engraving, an art which is thought to have been introduced from Rome.

Engraving has been performed in different countries, and at different periods of time, on various substances, chiefly on metals, wood, and the oriental precious stones, which are called gems, but with instruments that have varied but little since they were first invented. The metals upon which engraving is chiefly employed, are copper and steel, the former for producing impressions on paper in various ways, the latter for striking coins, medals, &c. Engraving on copper, for the purpose of producing impressions on paper, may almost be said to be an art of modern invention; for though the ancients ornamented their armour, metal vases, &c., by this means, they appear never to have thought of printing from the incisions, or lines, cut with the graver, nor was it thought of till about the middle of the 15th century. This art is chiefly employed in representing historical subjects, landscapes, portraits, &c., after pictures, or other designs made for the purpose.

Engraving on copper, for the purpose of producing impressions on paper, may be divided into several species; as engraving in aquatinta; in the chalk manner; with aquafortis; engraving on mezzotinto, and the original art of engraving in lines. We shall begin with the latter.

Engraving is the cutting lines upon a copper-plate, by means of a steel instrument called a graver, without the use of aquafortis. This, as we have observed, was the first way of producing copper-plate prints that was practised, and is still much used in historical subjects, portraits, and in finishing landscapes. The tools necessary for this art are, gravers, a scraper, a burnisher, an oil-stone, a sand bag, an oil rubber, and some good charcoal. The gravers are made of tempered steel, fitted into short wooden handles. They are square and lozenge-shaped. The first are used in cutting broad strokes, the other for fainter and more delicate lines. The scraper is a three-edged tool, for rubbing off the burr raised by the graver. Burnishers are for reducing lines that are too deep, or burnishing out any scratches or holes in the copper: they are of hard steel, rounded and polished. The oil-stone is for whetting the gravers, etching points, &c. The sand-bag, or cushion, is for laying the plate upon, for the conveniency of turning it in any direction. The oil rubber and charcoal are for polishing the plate. As great attention is required to whet the graver, particularly the belly of it, care must be taken to lay the two angles of the graver which are to be held next the plate, flat upon the stone, and rub them steadily, till the belly rises gradually above the plate; otherwise it will dig into the copper, and then it will be impossible to keep a point, or execute the work with freedom. For this purpose, keep your right arm close to your side, and place the fore-finger of your left hand upon that part of the graver which lies uppermost on the stone. In order to whet the face, place the flat part of the handle in the hollow of the hand, with the belly of the graver upwards, upon a moderate slope, and rub the extremity upon the stone, till it has an exceedingly sharp point. When the graver is too hard, as may be known by the frequent breaking of the point, the method of tempering it is as follows: Heat a poker red-hot, and hold the graver upon it, within half an inch of the point, till the steel changes to a light straw colour; then put the point into oil to cool; or, hold the graver close to the flame of a candle, till it be of the same colour, and cool it in the tallow. Be not hasty in tempering; for sometimes a little whetting will bring it to a good condition, when it is but a little too hard. To hold the graver, cut off that part of the handle which is upon the same line with the belly, or sharp edge of the graver, making that side flat, that it may be no obstruction. Hold the handle in the hollow of the hand, and extending your fore-finger towards the point, let it rest on the back of the graver, that you may guide it flat and parallel with the plate.

To lay the design upon the plate, after you have polished it fine and smooth, heat it so that it will melt virgin-wax, with which rub it thinly and equally over, and let it cool. Then the design which you are about to lay on, must be drawn on paper, with a black-lead pencil, and laid upon the plate, with its pencilled side upon the wax; then press it, and with a burnisher go over every part of the design, and when you take off the paper, you will find all the lines which you drew with the

the black-lead pencil upon the waxed plate, as if it had been drawn on it; then with a sharp pointed tool trace the design through the wax upon the plate, and you may then take off the wax, and proceed to work. Let the table or board you work at, be firm and steady; upon which place your sand-bag with the plate upon it, and, holding the graver as above directed, proceed in the following manner: For straight strokes, move the right hand forwards; leaning lighter where the stroke should be fine, and harder where you would have it broader. For circular or crooked strokes, hold the graver firmly, moving your hand or the plate, as you see convenient. Learn to carry the hand with such dexterity, that you may end your stroke as finely as you began it; and if you have occasion to make one part deeper or blacker than another, do it by degrees: and take care that your strokes be not too close, nor too wide. In the course of your work, scrape off the roughness which arises, with your scraper; but be careful not to scratch the plate, and that you may see your work properly as you go on, rub it with the oil-rubber, and wipe the plate clean, which will take off the glare of the copper, and shew what you have done to advantage. Any mistakes or scratches in the plate may be rubbed out with the burnisher, and the part levelled with the scraper, polishing it again lightly with the burnisher, or charcoal. Having thus attained the use of the graver, according to the foregoing rules, you will be able to finish the piece, by graving up the several parts to the colour required; beginning with the fainter parts, and advancing gradually with the stronger, till the whole is completed. The dry point or needle (so called because not used till the ground is taken off the plate) is principally employed in the extremely light parts of water, sky, drapery, architecture, &c.

After all, in the conduct of the graver and dry point, it is difficult to lay down rules which shall lead to eminence in the art. Every thing seems to depend on the habit, disposition, and genius of the artist. A person cannot expect to excel very much in engraving, who is not a good master of design, and he ought to be well acquainted with perspective, the principles of architecture, and anatomy. He will, by these means, be able, by proper degradations of strong and faint tints, to throw backward and bring forward the figures, and other objects of a picture or design, which he proposes to imitate. To preserve equality and union in his works, the engraver should always sketch out the principal objects of his piece before he undertakes to finish them. In addition to the rules already given, we may observe, that the strokes of the graver should never be crossed too much in the lozenge manner, particularly in the representations of muscle or flesh, because sharp angles produce the unpleasing effect of lattice-work, and take from the eye the repose which is agreeable to it, in all kinds of picturesque designs: there are exceptions to this rule, as in the case of clouds, the representation of tempests, waves of the sea, the skins of hairy animals, or the leaves of trees, in which this method of crossing may be admitted.

In managing the strokes, the actions of the figures, and of all their parts, should be considered, and, as in painting, it should be observed how they advance towards or recede from the eye, and the graver must, of course, be guided according to the risings or the cavities of the muscles or folds, making the strokes wider and fainter in the light, and closer and firmer in the shades; thus the figures will not appear jagged, and the outlines may be formed and terminated without being cut too hard. However, though the strokes break off where the muscle begins, yet they ought always to have a certain connexion with each other, so that the first stroke may often serve by its return to make the second, which will shew the freedom and taste of the artist. In engraving the muscles of the human figure, the effect may be produced in the lighter parts, by what are called long pecks of the gravers, or by round dots, or by dots a little lengthened, or what will be better, by a judicious mixture of these together. With regard to the hair, the engraver should begin his work by laying the principal grounds, and sketching the chief shades with a few strokes, which may be finished with finer and thinner strokes to the extremities. In the representation of architecture, the work ought not to be made too black, because as the edifices are usually constructed with stone, marble, &c., the colour, being reflected on all sides, does not produce dark shades, as is the case of other substances. Where sculpture is to be represented, white points must not be put in the pupils of the eyes of the figures, and in engravings after paintings; nor must the hair or beard be represented as in nature, which makes the locks appear flowing in the air, because, as is evident, in sculpture there can be no such appearances.

It is impossible to lay down rules that shall apply to all the subjects concerned in this art, since it is required that they must be varied with almost every substance: thus, to instance the engraving cloths of different kinds, linen should be done with finer and closer lines than other sorts of stuff, and should be executed with single strokes. Woollen cloth should be engraved wide: shining stuffs, as silk or sattin, which are known to produce flat and broken folds, should be engraved harder and straighter than the others. Velvet and plush should be always interlined. Metals are also represented by interlining, or by clear single strokes. Calm waters are best represented by strokes that are straight and parallel to the horizon, interlined with those that are finer, omitting such places as, in consequence of gleams of light, exhibit the shining appearance of water; and the forms of objects reflected from the water, are expressed by the same strokes, retouched more strongly, or faintly, as occasion may require. For agitated waters, as the waves of the sea, the first strokes should follow the waves, and may be interlined. In cascades, the strokes should follow the fall. In landscapes,

scapes, the trees, rocks, earth, and herbage, should be etched as much as possible: nothing is to be left to the graver, but perfecting, softening, and strengthening. The dry point produces an effect more delicate than the graver can, and may be used to great advantage in linen, skies, distances, ice, and often water. In almost every thing it is proper to etch the shadows, only leaving the lighter tints for the dry point, graver, &c.

To prevent any obstruction from too great a degree of light, the use of a sash made of transparent or fan paper, pasted on a frame, and placed sloping at a convenient distance between your work and the light, will preserve the sight; and when the sun shines, it cannot possibly be dispensed with.

Of Mezzotinto Scraping.—This art, which is of late date, is recommended by the ease with which it is executed, especially by those who understand drawing. Mezzotinto prints are those which have no strokes of the graver, but whose lights and shades are blended together, and appear like a drawing in Indian-ink. They are different from aquatinta; but as both resemble Indian-ink, the difference is not easily described. Mezzotinto is applied to portraits and historical subjects; and aquatinta is chiefly used for landscape and architecture. The tools necessary for mezzotinto scraping, are, the grounding-tool, burnishers, and scrapers. To lay the mezzotinto ground, lay your plate, with a piece of flannel under it, upon the table, hold the tool in your hand perpendicularly; lean upon it moderately hard, continually rocking your hand in a right line from end to end, till you have wholly covered the plate in one direction; next cross the strokes from side to side, afterwards from corner to corner, working the tool each time all over the plate, in every direction, almost like the points of a compass; taking care not to let the tool cut (in one direction) twice in a place. This done, the plate will be full, and would, if it were printed, appear completely black. Having laid the ground, take the scrapings of black chalk, and with a piece of rag rub them over the plate; or the plate may be smoked with candles. Now take the drawing, and having rubbed the back with red chalk-dust, mixed with flake-white, proceed to trace it on the plate. To form the lights and shadows, take a blunt needle, and mark the outlines only, then scrape off the lights in every part of the plate, as clean and smooth as possible, in proportion to the strength of the lights in your drawing, taking care not to hurt the outlines. The use of the burnisher is to soften the extreme light parts after the scraper is done with; such as the tip of the nose, forehead, linen, &c., which might otherwise, when proved, appear rather misty than clear.

Another method used by mezzotinto scrapers, is, to etch the outlines of the original, and the folds in drapery, making the breadth of the shadows by dots, which having bit to a proper depth with aquafortis, they take off the ground used in etching, and having laid the mezzotinto ground, proceed to scrape as above described. When the plate is ready, send it to the copper-plate printer, and get it proved. When the proof is dry, touch it with white chalk where it should be lighter, and with black chalk where it should be darker: and when the print is re-touched, proceed as before, for the lights; and for the shades, use a small grounding tool; prove it again; and so proceed to prove and touch, till it is entirely to your mind.

Mr. Robert Lawrie, in the year 1776, proposed to the Society for the Encouragement of Arts, Manufactures, &c., a new method of printing mezzotinto prints in colours, for which he received a premium of thirty guineas. He says he was induced to attempt this method, owing to the great expense attending the execution of good engravings, which had more than answered his most sanguine expectations. In this manner, animals, plants, &c., for illustrating Natural History, may be finished in their proper colours, very much like drawings, and greatly resembling nature. The plates will also admit of being repaired, so as to furnish a large impression. The following is an explanation of his method:

A copper-plate with an etched or engraved outline, dotted next the lights, and filled in with mezzotinto ground, is printed in colours after nature, or from a picture, by the following process. The plate being warmed in the usual manner, the colours are applied by means of stump camel-hair pencils to the different parts, as the subject suggests; it is then wiped with a coarse gauze canvass, any other being improper; after this, it is wiped clean with the hand, and being again warmed, is passed through the press. The colours are mixed with burnt linseed oil, and those generally used by painters are proper.

Of Engraving in Aquatinta.—Aquatinta is a method of producing prints very much resembling drawings in Indian-ink. The principle of the process consists in corroding the copper with aquafortis, in such a manner, that an impression from it has the appearance of a tint laid on the paper. This is effected by covering the copper with a powder, or some substance which takes a granulated form, so as to prevent the aquafortis from acting where the particles adhere, and by this means cause it to corrode the copper partially, and in the interstices only. When these particles are extremely minute and near to each other, the impression from the plate appears to the naked eye exactly like a wash of Indian-ink; but when they are larger, the granulation is more distinct, and as this may be varied at pleasure, it is capable of being adapted with great success, to a variety of purposes and subjects.

This powder, or granulation, is called the aquatinta grain, and there are two general modes of producing it. We shall first describe what is called the powder-grain, because it was the first that was used. Having etched the outline on a copper-plate, prepared in the usual way by the coppersmith, some of the substance must be finely powdered and sifted, which will melt with heat, and when cold will adhere to the plate, and resist the action of

of aquafortis. The substances which have been used for this purpose, either separately or mixed, are asphaltum, Burgundy pitch, rosin, gum copal, gum-mastich; and in a greater or less degree, all the resins and gum-resins will answer the purpose. Common rosin has been most generally used, and answers tolerably well; though gum copal makes a grain that resists the aquafortis better. The substance intended to be used for the grain, must now be distributed over the plate as equally as possible; and different methods of performing this essential part of the operation have been used by different engravers, and at different times. The most usual way, is to tie up some of the powder in a piece of muslin, and strike it against a piece of stick, held at a considerable height above the plate; by this, the powder that issues falls gently, and settles equally over the plate. Every one must have observed how uniformly hair-powder settles upon the furniture after the operations of the hair-dresser, which may afford a hint towards the best mode of performing this part of the process. The powder must fall upon it from a considerable height, and there must be a sufficiently large cloud of the dust formed. The plate being covered equally over with the dust, or powder, the operator is next to proceed to fix it upon the plate, by heating it gently, so as to melt the particles. This may be effected by holding under the plate lighted pieces of brown paper rolled up, and moving them about till every part of the powder is melted; this will be known by its change of colour, which will turn brownish. It must now be suffered to cool, when it may be examined with a magnifier, and if the grains or particles appear to be uniformly distributed, it is ready for the next part of the process. The design or drawing to be engraved must now be examined, and such parts of it as are perfectly white are to be remarked. Those corresponding parts of the plate must be covered or stopped out, as it is called, with turpentine-varnish, diluted with turpentine to a proper consistence, to work freely with the pencil, and mixed with lamp-black to give it colour; for if transparent, the touches of the pencil would not be so distinctly seen. The margin of the plate must also be covered with varnish. When the stopping-out is sufficiently dry, a border of wax must be raised round the plate, in the same manner as in etching, and the aquafortis, properly diluted with water, poured on. This is called biting in, and is the part of the process which is most uncertain, and which requires the greatest degree of experience. When the aquafortis has lain on so long that the plate, when printed, would produce the lightest tint in the drawing, it is poured off, and the plate washed with water and dried. When it is quite dry, the lightest tints in the drawing are stopped out, and the aquafortis poured on as before; and the same process is repeated as often as there are tints to be produced on the plate. Although many plates are etched entirely by this method of stopping out and biting in alternately, yet it may easily be conceived, that in general, it would be very difficult to stop round, and leave out all the finishing touches, as also the leaves of trees, and many other objects, which it would be impossible to execute with the necessary degree of freedom in this manner. To overcome this difficulty, another very ingenious process has been invented, by which these touches are laid on the plate with the same ease and expedition as they are in a drawing in Indian-ink. Fine washed whiting is mixed with a little treacle or sugar, and diluted with water in the pencil, so as to work freely, and this is laid on the plate covered with the aquatint ground, in the same manner and on the same parts as ink on the drawing. When this is dry, the whole plate is varnished over with a weak and thin varnish of turpentine, asphaltum, or mastich, and then suffered to dry, when the aquafortis is poured on. The varnish will immediately break up in the parts where the treacle mixture was laid, and expose all those places to the action of the acid, while the rest of the plate remains secure. The effect of this will be, that all the touches or places where the treacle was used will be bit in deeper than the rest, and will have all the precision and firmness of touches in Indian-ink. After the plate is completely bit-in, the bordering-wax is taken off, by heating the plate a little with a lighted piece of paper; and it is then cleared from the ground and varnish by oil of turpentine, and wiped clean with a rag and a little fine whiting, when it is ready for the printer. The principal disadvantages of this method of aquatinting are, that it is extremely difficult to produce the required degree of coarseness or fineness in the grain, and that plates so engraved do not print many impressions before they are worn out. It is therefore now very seldom used, though it is occasionally of service.

We next proceed to describe the second method of producing the aquatint ground, which is generally practised. Some resinous substance is dissolved in spirits of wine, as common rosin, Burgundy pitch, or mastich, and this solution is poured all over the plate, which is then held in a slanting direction till the superfluous fluid drains off; and it is laid down to dry, which it does in a few minutes. If the plate be then examined with the magnifier, it will be found that the spirit in evaporating has left the resin in a granulated state, or rather that the latter has cracked in every direction, still adhering firmly to the copper. A grain is thus produced with the greatest ease, which is extremely regular and beautiful, and much superior for most purposes to that produced by the former method. After the grain is formed, every part of the process is conducted in the same manner as has been described.

Having thus given a general idea of the art, we shall mention some particulars necessary to be attended to, in order to ensure success in the operation. The spirits of wine used for the solution must be highly rectified and of the best quality. What is sold in the shops generally contains camphire, which would entirely spoil the grain. Rosin, Burgundy pitch, and gum-mastic, when dissolved in spirits of wine, produce grains of a different

appearance and figure, and are sometimes used separately and sometimes mixed in different proportions, according to the taste of the artist, some using one substance and some another. In order to produce a coarser or finer grain, it is necessary to use a greater or smaller quantity of resin; and to ascertain the proper proportions several spare pieces of copper must be provided, on which the liquid may be poured and the grain examined before it is applied to the plate to be engraved. After the solution is made it must stand still and undisturbed for a day or two, till all the impurities of the resin have settled to the bottom and the fluid is quite pellucid. No other method of freeing it from those impurities has been found to answer; straining it through linen or muslin only fills it with hairs, which are ruinous to the grain. The room in which the liquid is poured on the plate must be perfectly still and free from dust, which, whenever it falls on the plate while wet, causes a white spot, that it is impossible to remove without laying the grain afresh. The plate must also be previously cleaned with the greatest possible care with a rag and whiting, as the smallest stain or particle of grease produces a streak or blemish in the grain. All these attentions are absolutely necessary to produce a tolerably regular grain; and, after every thing that can be done by the most experienced artists, still there is much uncertainty in the process. They are sometimes obliged to lay on the grains several times, before they procure one sufficiently regular. The same proportions of materials do not always produce the same effect, as it depends in some degree on their qualities: and it is even materially altered by the weather. These difficulties are not to be surmounted but by a great deal of experience; and those who are daily in the habit of practising the art are frequently liable to the most unaccountable accidents. Indeed, it is much to be lamented that so elegant and useful a process should be so extremely delicate and uncertain. It being necessary to hold the plate in a slanting direction in order to drain off the superfluous fluid, there will naturally be a greater body of the liquid at the bottom than at the top of the plate. On this account, a grain laid in this way is always coarser at the side of the plate that was held lowermost. The most usual way is to keep the coarsest side for the fore ground, that being generally the part which has the deepest shadows. In large landscapes sometimes various parts are laid with different grains, according to the nature of the subject. The finer the grain is the more nearly does the impression resemble Indian-ink, and the fitter it is for imitating drawings: but very fine grains have several disadvantages; for they are apt to come off before the aquafortis has lain on long enough to produce the desired depth; and as the plate is not corroded so deep, it sooner wears out in printing, whereas coarser grains are firmer, the acid goes deeper, and the plate will throw off a great many more impressions. The reason of all this is evident, when it is considered that in the fine grains the particles are small and near each other, and consequently the aquafortis, which acts laterally as well as downwards, soon undermines the particles and causes them to come off. If left too long on the plate, the acid would eat away the grain entirely. On these accounts, therefore, the moderately coarse grains are more sought after, and answer better the purpose of the publisher than the fine grains which were formerly in use. Although there are considerable difficulties in laying properly the aquatint grain, yet the corroding the copper, or biting-in, so as to produce exactly the tint required, is still more precarious and uncertain. All engravers allow that no positive rules can be laid down, by which the success of this process can be secured; nothing but a great deal of experience and attentive observation can enable the artist to do it with any degree of certainty. There are some hints, however, which may be of considerable importance to the person who wishes to attain the practice of this art. It is evident that the longer the acid remains on the copper the deeper it bites, and consequently the darker will be the shade in the impression. It may be of some use, therefore, to have several bits of copper laid with aquatint grounds of the same kind to be used in the plate, and to let the aquafortis remain for different lengths of time on each; and then to examine the tints produced in one, two, three, four minutes, or longer. Observations of this kind frequently repeated, and with different degrees of strength of the acid, will at length assist the judgment in guessing at the tint which is produced in the plate. A magnifier is also useful to examine the grain, and to observe the depth to which it is bit. It must be observed, that no proof of the plate can be obtained till the whole process is finished. If any part appears to have been bit too dark it must be burnished down with a steel burnisher; but this requires great delicacy and good management not to make the shade streaky; and as the beauty and durability of the grain are always somewhat injured by it, it should be avoided as much as possible. Those parts which are not dark enough must have a fresh grain laid over them, and be stopped round with varnish, and subjected again to the aquafortis. This is called re-biting, and requires peculiar care and attention. The plate must be very well cleaned out with turpentine before the grain is laid on, which should be pretty coarse, otherwise it will not lay upon the heights only, as is necessary in order to produce the same grain. If the new grain is different from the former it will not be so clear nor so firm, but rotten. We have now given a general account of the process of engraving in aquatint, and we believe that no material circumstance has been omitted that can be communicated without seeing the operation; but after all, it must be confessed that no printed directions whatever can enable a person to practise it perfectly. Its success depends upon so many niceties and attention to circumstances apparently trifling, that the person who attempts it must not be surprised if he does not succeed at first. It is a species of engraving simple and expeditious, if every thing goes on well; but it is very precarious,

precarious, and the errors which are made are rectified with great difficulty.

It seems to be adapted chiefly for imitation of sketches, washed drawings, and slight subjects; but does not appear to be at all calculated to produce prints from finished pictures, as it is not susceptible of that accuracy in the balance of tints necessary for this purpose. Nor does it appear to be suitable for book-plates, as it does not print a sufficient number of impressions. It is therefore not to be put in competition with the other modes of engraving. If confined to those subjects for which it is calculated, it must be allowed to be extremely useful, as it is expeditious, and may be attained with much less trouble than any other mode of engraving. But even this circumstance is a source of mischief, as it occasions the production of a multitude of prints that have no other effect than that of vitiating the public taste. Engraving in aquatint was invented by Le Prince, a French artist, who kept his process a long time secret, and it is said he sold his prints at first as drawings; but he appears to have been acquainted only with the powder-grain and the common method of stopping-out. The prints which he produced are still some of the finest specimens of the art. Mr. Paul Sandby was the first who practised it in this country, and it was by him communicated to Mr. Jukes. It is now practised very generally all over Europe, but no where more successfully than in this kingdom.

We now come to *Etching*; an important branch of the art of engraving, in which the lines or strokes, instead of being cut with a tool or graver, are corroded or bit in with nitrous acid. In almost all engravings on copper that are executed in the stroke manner, etching and graving are combined, the plate being generally begun by etching and finished by the hand of the engraver. Subjects that receive the most assistance from the art of etching are landscapes, architecture, and machinery. It is not applicable, or only in a small degree, to portraits and historical designs. In describing the instruments and materials used in this art, we may observe that copper-plates on which the designs are made may be obtained ready prepared at the coppersmiths.

Etching-points or needles are pointed instruments of steel about an inch long, fixed in handles of hard wood about six inches in length, and of the size of a large goose-quill. They should be made of well tempered metal, and fixed very firmly in the centre of the handle. They must be brought to an accurately conical point by rubbing upon an oil stone. A parallel ruler is necessary for drawing parallel straight lines, though Mr. Lowry, Mr. Porter and others substitute for this a machine to be described that greatly facilitates the labour, and performs the work with more accuracy and regularity.

Nitrous acid is used for corroding or *biting-in* the rough sketch of the engraving. The bordering wax for surrounding the margin of the copper-plate when the acid is to be poured on, is composed of one part of bees-wax and two parts of pitch. These are to be melted together in an iron ladle, and when melted to be thrown into warm water, after which they are to be moulded into rolls of a convenient size.

Turpentine varnish is used for covering the copper-plate in those parts which are not to be corroded with the acid. This varnish is to be mixed with lamp-black, that it may be seen better when laid upon the plate. The etching-ground is used for covering the plate, previously to drawing the lines upon it with the needles. The composition of this is thus described: take of virgin-wax and asphaltum, each a pound and a quarter, of black pitch and Burgundy pitch each half an ounce; melt the wax and pitch together in an earthen pipkin, and add to them by degrees the asphaltum finely powdered. The whole is now to be boiled together, and when sufficiently boiled it is to be poured into warm water and formed into balls for use.

To lay the ground for etching, proceed in the following manner: having cleaned the copper-plate with some fine whiting and a linen rag, to free it from all grease, fix a hand-vice to some part of it where no work is intended to be, to serve as a handle for managing it by when warm. Roll up some coarse brown paper, and light one end; then hold the back of the plate over the burning paper, moving it about until every part of it is equally heated, so as to melt the etching-ground, which should be wrapped up in a bit of taffeta, to prevent any dirt that may happen to be among it, from mixing with what is melted upon the plate. If the plate be large, it will be best to heat it over a chafing-dish with some clear coals. It must be heated just sufficient to melt the ground, but not so much as to burn it. When a sufficient quantity of the etching-ground has been rubbed upon the plate, it must be dabbed, or beat gently, while the plate is hot, with a small dabber made of cotton wrapped up in a piece of taffeta, by which operation the ground is distributed more equally over the plate than it could be by any other means.

When the plate is thus uniformly and thinly covered with the varnish, it must be blackened by smoking it with a wax-taper. For this purpose twist together three or four pieces of wax-taper, to make a larger flame, and while the plate is still warm, hold it with the varnished side downwards, and move the smoky part of the lighted taper over its surface, till it is made almost quite black; taking care not to let the wick touch the varnish, and that the latter get no smear or stain. In laying the etching-ground, great care must be taken that no particles of dust or dirt of any kind settle upon it, as that would be found very troublesome in etching; the room therefore in which it is laid should be as still as possible and free from dust.

The ground being now laid, and suffered to cool, the next operation is to transfer the design to the plate.

For this purpose a tracing on oiled paper must now be made, from the design to be etched, with pen and ink, having a very small quantity of ox's gall mixed with

with it, to make the oiled paper take it; also a piece of thin paper of the same size, must be rubbed over with red chalk, powdered, by means of some cotton. Then laying the red chalked paper, with its chalked side next the ground, on the plate, put the tracing over it, and fasten them both together, and to the plate, by a little bit of the bordering-wax.

When all this is prepared, take a blunt etching needle, and go gently all over the lines in the tracing; by which means the chalked paper will be pressed against the ground, and the lines of the tracing will be transferred to the ground: on taking off the papers, they will be seen distinctly.

The plate is now prepared for drawing through the lines which have been marked upon the ground. For this, the etching-points or needles are employed, leaning hard or lightly, according to the degree of strength required in the lines. Points of different sizes and forms are also used, for making lines of different thickness, though commonly this is effected by the biting-in with the aquafortis.

A margin or border of wax must now be formed all round the plate, to hold the aquafortis when it is poured on. To do this, the bordering-wax already described must be put into lukewarm water to soften it, and render it easily worked by the hand. When sufficiently pliable, it must be drawn out into long rolls, and put round the edges of the plate, pressing it down firm, and forming it with the fingers into a neat wall or margin. A spout must be formed in one corner, to pour off the aquafortis by afterwards.

The nitrous acid is now to be diluted with four or five times as much water, or more, according as the plate is to be bit quick or slow, and poured upon the plate. In a few minutes you will see minute bubbles of air filling all the lines that have been drawn on the copper, which are to be removed by a feather; and the plate must be now and then *swept*, as it is called, or kept free from air-bubbles. By the more or less rapid production of these bubbles, you judge of the rapidity with which the acid acts upon the copper. The biting-in of the plate is the most uncertain part of the process, and nothing but very great experience can enable any one to tell when the plate is bit enough, as you cannot easily see the thickness and depth of the line till the ground is taken off.

When you judge, from the time the acid has been on, and the rapidity of the biting, that those lines which you wish to be the faintest are as deep as you wish, you pour off the aquafortis by the spout, wash the plate with water, and dry it by blowing with bellows, or by the fire, taking care not to melt the ground. Those lines that are not intended to be bit any deeper, must now be stopped up with turpentine-varnish mixed with a little lamp-black, and laid on with a camel's-hair pencil; and when this is thoroughly dry, the aquafortis may be poured on again, to bite the other lines that are required to be deeper. This process of stopping-out and biting-in, is to be repeated as often as there are to be lines of different degrees of thickness, taking care not to make any mistake in stopping-out wrong lines.

It is also necessary to be particularly careful to stop-out with the varnish, those parts from which the ground may happen to have come off by the action of the acid, otherwise you will have parts bit that were not intended, which is called *foul-biting*. When the biting-in is quite finished, the next operation is to remove the bordering-wax and the ground, in order that you may see what success you have had; for till then, this cannot be known exactly. To take off the bordering-wax, the plate must be heated by a piece of lighted paper, which softens the wax in contact with the plate, and occasions it to come off quite clean. Oil of turpentine is now poured upon the ground, and the plate is rubbed with a bit of linen rag, which removes all the ground. Lastly, it is cleaned off with whitening.

The success of the etching may now be known, but it is necessary to get an impression taken upon paper by a copper-plate printer. This impression is called a *proof*.

If any parts are not bit so deep as were intended, the process may be repeated, provided the lines are not too faintly bit to admit of it. This second biting-in the same lines, is called *re-biting*, and is done as follows: melt a little of the etching-ground on a spare piece of copper, and dab it a little, to get some on the dabber; then, having cleaned out, with whiting, the lines that are to be re-bit, heat the plate gently, and dab it very lightly with the dabber. By this, the parts between the lines will be covered with the ground, but the lines themselves will not be filled up, and consequently will be exposed to the action of the aquafortis. This is a very delicate process, and must be performed with great care. The rest of the plate must now be varnished over, the bordering wax put on again, and the biting repeated in the same manner as at first.

If any part should be bit too deep, it is more difficult to recover it, or make it fainter: this is generally done by burnishing the part down, or rubbing it with a piece of charcoal. This will make the lines shallower, and cause them not to print so black.

Should any small parts of the lines have missed altogether in the biting, they may be cut with the graver: which is also sometimes employed to cross the lines of the etching, and thus to work up a more finished effect.

Dry-pointing, as it is technically called, is a method employed for softening the harsh effects usually apparent in an etching. This is done by cutting with the etching-point upon the copper without any ground or varnish. This does not make a very deep line, and is used for covering the light, where delicate tints and soft shadows are wanting. By varying these processes of etching, graving, and dry-pointing, the plate may be worked up to the full effect intended.

Engraving in *dots*, which has been very much practised within the last twenty years, is an old invention, and was the only mode discovered by the Italians. Augustine

Augustine of Venice, who flourished from 1509 to 1536, used it in several of his earliest works, but confined it to the representation of flesh, as in an undated print of an old man seated on a bank, with a cottage in the back-ground. It is seen, likewise, in a print of a single figure standing, holding a cup and looking upwards, by Giulio Campagnola. The back-ground is executed with round dots made apparently with a dry point. The figure is outlined with a stroke deeply engraved and finished with dots, in a manner greatly resembling prints engraved by Demarteau, at Paris, in imitation of red chalk. The hair and beard are expressed by strokes.

Having gone through the mechanical preparations, which require care and experience, the engraver's task as an artist or man of taste properly begins. He may now call forth his inventive powers. The forms of his objects must now be severally drawn, and his shadows, tints, and lights, excepting such as he may prefer to leave to be executed by the graver, or dry point, be etched by employing lines more close or more open, and pressing on his needles more lightly or strongly, in order that he may vary his lines with the nature of the object. The characteristic advantage of etching, for certain purposes, over lines cut with the graver, consists in the unlimited freedom of which this mode of art is susceptible. The etching-needle, meeting little resistance from the varnish, glides along the surface of the plate, and easily takes any turn that the taste of the artist may direct, or his hand accomplish; and hence it is well adapted to the expression of that class of objects which are denominated by the term picturesque, such as trees, rocks, ruins, cottages, the hair of animals, broken ground, or other rough and irregular surfaces.

With the view of etching subjects of these kinds, Mr. Lowry several years since invented and constructed divers instruments and machines which he has successfully employed in the fine engravings executed by his hand or under his direction. One of these was for etching successive lines either equi-distant, or in just graduation from being wide apart to almost the nearest approximation; the compass of the instrument being commensurate with every possible demand of art. Another machine is for striking elliptical, parabolical, and hyperbolical curves, and, in general, all those lines which are known by geometricians under the denomination of geometrical curves, from the dimensions of the point of a needle to an extent of four or five feet. He has also constructed other machinery for facilitating particular operations of etching, and ensuring precision in describing arcs of circles of every radius, lines converging to points at all distances, various kinds of spiral lines and the cogs and smaller teeth of wheel-work. These inventions combine elegance and utility, and are of high value if only considered as auxiliaries of the imitative part of this branch of engraving, but as connected with the other departments of science, they are of incalculable advantage. The accuracy of their operations appears to be perfect, as far as can be ascertained by the human senses aided with powerful magnifying glasses. Mr. Lowry has never published an account of his machines: he, Mr. Porter, and others who make use of them endeavour to keep their construction a secret. To this Mr. William Nicholson alludes in his Journal for January 1799, and says, that upon his first hearing of the fact, he thought and asserted that it would be easy to make such a tool. He accordingly, at the intervals of his leisure, did accomplish the object. He disclaimed the merit of originality of thought in substituting mechanical operations instead of hand-work, and he adds "those who have seen the screw gear of Ramsden's great dividing engine will perceive that I have done little more than distribute the parts of this tool in what appeared to me to be the most simple and convenient manner." It is difficult to give an intelligible description of this machine without the aid of figures, and as the machine has not been deemed sufficiently perfect to get into general use, it does not seem to claim that degree of importance which engravings would bestow upon it. It consists of a frame fixed to a drawing-board, and resembles a sliding-rule and serves to guide a sliding-piece. There is a screw having forty threads to an inch; and there are two cocks, of which one is fixed to the frame, and bears a clip or pair of nuts, which open and shut with a joint like compasses, and either embrace the screw by a regularly tapped part when shut, or leave it at liberty when open. The other cock is fixed to the sliding piece: it carries a steel ruler, which though sufficiently strong, is thin enough to adapt itself to slight variations of thickness of the plate beneath it. "In my instrument," says Mr. Nicholson, "I have made it adjustable to much greater variations of thickness, by means of an horizontal axis; but as this contrivance adds to the expense, and diminishes the simplicity of the instrument, I would rather recommend that great variations should be allowed for by putting paper or thin slips of metal underneath the plate as may be required." The end of the screw is turned down, and fixed in the cock by means of a nut and washer: the upper part of the cock is filed round, and cut into teeth, of which fifty would complete the whole circle. The centre of this external circular part corresponds with the axis of the screw, and there are shewn in the figure two short cylindrical pieces which are hollow, and apply to each other so as to form a kind of box. Within, and fixed to one of these cylindrical pieces, which is fixed to the screws itself, there is a ratchet wheel divided into 50 teeth; and within the cylindrical piece there is a ratchet wheel, which holds when the said piece is moved by its handle from right to left, but which escapes when that handle is moved in a contrary direction. The lever or arm is likewise supported by the stem of the screw, and occupies the remaining space between the handle and the cock. At the outer extremity of this lever there is a small steel blade, which, by means of a back spring exactly resembling that of a pocket knife, may be made to form a continuation of the lever itself, or by being

placed at right angles to the lever, may be made to rest in any of the divisions between the teeth of the circumference of the cock, and consequently will by that means confine the lever to the position in which it is placed. The handle cannot pass the lever because this last is too thick, and there is a stud or pin upon the face of the cock, which prevents the handle from being moved beyond a certain determinate station to the left hand. And, lastly, the ruler may be of any required length, and serves, by means of a thumb-screw at one end, and another at the opposite end, to secure the copper-plate against the drawing-board in the usual manner.

Such is the construction of the machine: its use is thus set forth:—By drawing back a claw, the screw is set at liberty, and the ruler may be brought to any required distance by hand. The plate may then be duly placed and secured to the board, and the clip drawn gently together by the claw. In this situation, if the lever be placed at a considerable distance from the handle, that handle may be moved to the right, during which the click will gather upon the ratchet-wheel; and then being returned to the left, it will carry the screw round. The gentle pressure, exerted by means of the claw, will tend to close the clip upon the screw, as soon as it comes into a fair position by its rotation; at which instant the claw will suddenly fall into its place, and the machine is ready for work, excepting that the adjustment for the fineness or coarseness of the stroke must be first made. This is done by the lever. If the steel blade be dropped into the first notch beginning on the left hand, the handle will be confined; if at the second notch, the handle, upon being moved backwards and forwards between the pin and lever, will move the screw through one tooth, or the one-fiftieth of a turn each time, and consequently will carry the ruler through the $\frac{1}{2000}$th part of an inch. If the blade of the lever be placed in any other of the notches, the quantity passed over, at each return of the handle, will be greater or less according to the number. As there are but twenty-six notches, the greatest single shift of this instrument will be the $\frac{1}{80}$th part of an inch; but as this shift is so readily made, it is easy, even with this fine screw, to reach greater intervals, by moving the handle once, twice, or even three times, between stroke and stroke. Thus, for the $\frac{1}{50}$th of an inch, or $\frac{40}{2000}$ths, the number of intervals cannot be passed over at one stroke; but if the blade be set at the twentieth notch, the ruler will be shifted exactly that quantity, by two movements of the handle.

Soon after Mr. Nicholson had given this account to the public, Mr. Lowry permitted him to take a view of his machine for ruling, which he found to be entirely different from the one just described. "As he, (Mr. Lowry,) has no actual division in the part which produces the shift, he can regulate his distances to incommensurate, as well as commensurate measures. The parallax of the ruling point, against which I had made no provision, is, by a very simple and happy contrivance, taken away in common ruling, or rendered variable at pleasure, for the purpose of thickening the stroke in shading."

Engravers have frequently complained of the inconvenience which they experience from the fumes which proceed from the action of the nitrous acid upon the copper, when the plate is large. To remedy this, Mr. Cornelius Varley recommends that the artist should get a frame made of deal, three or four inches deep, covered with a plate of glass, and open at one side; the side opposite to this is to have a round opening communicating, by means of a common iron pipe, with the ash-pit of any little stove or other fire-place, shut up from all other access of air but what must pass through the pipe. Any fumes rising from a copper-plate laid under such a frame will be carried backward into the iron-pipe by the current of air required to maintain combustion in the stove, and will by this means be carried up the chimney, in place of being allowed to fly about in the apartment. The pipe may be used by carrying it down through the table to the floor, and so along to the place wherever the chimney is; and when the frame is not wanted, the pipe, at one of the joinings, may be made to answer the purpose of a hinge, by which to turn up the frame against the wall, where it may be secured, while out of use, by a button, &c.

Before we conclude this article, we may give an account of another subject or two closely connected with it. Of these, the first is Mr. Samuel Toplis's (of Gainsborough) method of writing and engraving in oil, and multiplying copies on paper, parchment, linen, and other materials of flexible texture, which is as follows: Have in readiness a well-polished, silver, copper, or other metal plate, or earthen-ware, or horn, and have ready a cushion, or as a substitute for a cushion, a fresh bladder filled with air. On the cushion, or its substitute, with a painter's brush, a knife, a folding-stick, or other convenient instrument, spread a fine coat of strong printing ink, or in the absence of this, paint, or other substance of a viscous nature may be used, provided it be of such a consistence as will admit of separation without running. Take the plate, holding it by the corners alternately, and suffer it to touch the ink, paint, &c., by gentle pattings or fallings of the plate, till the whole become coated. With a piece of hard wood reduced to a point fit for making strokes, engrave or delineate the subject required. The plate thus coated, engraved, or delineated, must be then taken to a rolling-press, and on it lay a dry or a moist sheet of paper, skin of parchment, or leather, &c.; on any of these lay a woollen cloth, or other such body, and giving the requisite pressure, there will be found a fair copy of all matters engraved or otherwise delineated on the coated plate, in white characters. If more than one copy is required, the force meant to be applied must be divided by the number of copies wanted. This invention, says the author of it, is intended to convey useful knowledge, or the delineations of fancy, to the various parts of the habitable globe, in a different and more

more curious manner than by any other means that have hitherto been practised or attempted. The art may be extended through the mediums of painting, japanning, calico-printing, to all bodies possessing plain surfaces, of whatever shape or use, amidst our various arts and manufactures; for it is able to figure that essential part of dress, linen, in a cheaper and readier way than by any yet adopted.

The following is a description of a moveable table for the use of engravers, invented by the Abbé Joseph Longhi, a very ingenious Italian artist. He was led to this by observing how common it is for engravers to die at an early period of their lives: "It too often happens," he says, "that those artists who apply themselves the most assiduously to their art, fall early victims to their diligence, so that their first essays become their last works." Reflecting on the causes that led to this, he found it to proceed from the very hurtful attitude in which the engraver is placed at his work; for in engraving a plate, even of a middling size, if the plate be placed horizontally upon a cushion, it is not only impossible to perform the work without a very injurious curvature of the body; but it lays the foundation of those complaints which so often prove fatal to artists. The intention of the Abbé, in the invention of the table now to be described, was, that those artists should be able to work either standing or sitting, without any injurious bending of the body; for this purpose he began by placing the copper-plate upon a desk, revolving on a centre, but he soon found that one centre was insufficient; it became necessary, therefore, that the board upon which the plate was to be fixed, should have a great number of square holes underneath, by which it might be put upon the axis or pivot in any part, as occasion might require. He says this table is much more commodious for engraving than any other method; for, when it is necessary to engrave in the corner of a plate, it is difficult to do it on a cushion in the usual way, that is, by supporting it with the left hand, and keeping it quite motionless; and the smallest motion in the plate renders it impossible to perform the work properly; but upon this table, where the plate is fixed upon a pivot or axis, and supported by a projecting part under it, the left hand has less to do, and the plate always turns round parallel to what it rests upon.

The upper or moveable part of the table consists of a thin plank, to the bottom of which is united an iron plate, with a number of square holes made to fit exactly that part of the axis which protrudes. The under-board is made to rise and fall at pleasure, in the manner of a desk, by means of a pair of hinges, in the middle of which is the thick protruding axis just mentioned, that comes through a circle of iron. There is also a still larger circle of iron, of the same height as the smaller one, that serves for the moveable board to rest upon, as it is turned round. There is a foot by which the desk part is supported at any required height.

Engraving on Wood.—Engraving on wood is a process exactly the reverse to engraving on copper. In the latter, the strokes to be printed are sunk, or cut into the copper, and a rolling-press is used for printing it; but in engraving on wood, all the wood is cut away, except the lines to be printed, which are left standing up like types, and the mode of printing is the same as that used in letter-press. The wood used for this purpose is box-wood, which is planed quite smooth. The design is then drawn upon the wood itself with black-lead, and all the wood is cut away with gravers and other proper tools, except the lines that are drawn. Or sometimes the design is drawn upon paper, and pasted upon the wood, which is cut as before. This art is of considerable difficulty, and there are comparatively very few who practise it. But of late years, the art of cutting designs upon wood has arrived at a vast degree of perfection, especially under the celebrated Bewicks, of Newcastle, who have carried their execution in this respect to a pitch of elegance rivalling, and in some instances, almost surpassing copper-plate engraving, which before their time was believed to be utterly unattainable.

On this subject Mr. P. Wilson, of Glasgow, observes, "Having often regretted that such rare specimens of art as they have produced were so perishable, from the frailness of the materials upon which so much genius and labour were expended, I was induced to send to Mr. Tassie, among other models, some designs in box-wood, executed by Mr. Bewick, with directions to mould from them, in the view of obtaining casts or copies in glass. The returns which I received to all those patterns completely answered my expectations, as being at once as perfect as the originals." From the success of this experiment, and from what has been established in the way of making glass safely resist any degree of pressure, it will readily occur, that an improvement of considerable magnitude may depend upon a proper co-operation of the two arts of engraving upon box-wood or upon brass, and of moulding, with a view of obtaining such cuts or engravings in so durable a substance as glass.

We shall resume this subject, under the head Glass-Making.

FILE-MAKING.

We shall introduce this article with some admirable observations on the progress of mechanical discovery, exemplified in an account of machines for cutting files, by Mr. Wm. Nicholson.

"The folly and consequent distress of pursuing experiments in chemistry, for the sole purpose of commercial advantage, has been repeatedly observed, both by public writers, and in private life. The obscurity which attends the processes of this art, the imperfections of theory, and the seductions of hope, have united to lead men in pursuit of medicines of uncommon powers, and agents which should convert the cheaper metals into gold and silver. It is a subject of no wonder, to those who have not suffered their mental habits to be vitiated by these seductive analogies, that difficulties and disappointment should attend the life of a man thus employed. But mechanics have, in general, been more favourably regarded. A number of simple and admirably useful effects are produced by the operation of machines. We daily see improvements produced by means easily understood. The mechanic, who endeavours to strike into a new path, finds he can reason from what has been done before him, and usually begins his work with a conviction that the results he is desirous of obtaining will infallibly happen. Hence it is, that a prodigious number of new schemes find their way into books, on which both the author and the reader set a high value, and of which the futility is discerned only by a few practical men. Some of my readers have supposed this source of information to be much more productive than it really is. A very slight inquiry concerning new machines and inventions, whether they have been carried into effect, and whether they have superseded the old methods of operation, will immediately strike out of the list of valuable articles not less than nine-tenths of the objects to which the public attention is solicited. And if it be asserted, that the description of such abortive projects might be of use to afford hints to speculators, I must take the liberty to observe, that it is a most serious thing to engage in a new invention, and a no less serious duty in the editor of a public work, to be well assured of the value of what he recommends or suffers to recommend itself to his readers. From views of this kind, it has appeared to me, that I should do some service to an active set of men, some of whom have effectually served this country, if I were concisely to point out the course of mechanical invention, in order that those individuals only may be induced to engage in it who possess the acquisitions and means to do it with some effect.

"We will therefore suppose a very acute theorist, who is not himself a workman, nor in the habit of superintending the practical execution of machinery, to have conceived the notion of some new combination of the mechanical powers to produce a determinate effect; and for the sake of perspicuity, let us take the example of a machine to cut files. His first conception will be very simple or abstracted. He knows that the notches in a file are cut with a chisel, driven by the blow of a hammer, by a man whose hands are employed in applying these instruments, while his foot is exerted in holding the file on an anvil by means of a strap. Hence he concludes, that it must be a very easy operation to fix the chisel in a machine, and cause it to rise and fall by a lever, while a tilting hammer of the proper size and figure gives the blow. But, as his attention becomes fixed, other demands arise, and the subject expands before him. The file must be supported upon a bed or mass of iron, of wood, of lead, or other material: it must be fixed either by screws, or wedges, or weights, or some other effectual and ready contrivance: and the file itself, or else the chisel, with its apparatus for striking, must be moved through equal determinate spaces during the interval between stroke and stroke, which may be done either by a ratchet-wheel or other escapement, or by a screw. He must examine all these objects, and his stock of means in detail; fix upon such methods as he conceives to be most deserving of preference; combine, organize, and arrange the whole in his mind; for which purpose, solitude, darkness, and no small degree of mental effort, will be required. And when this process is considerably advanced, he must have recourse to his drawing-board. Measured plans and sections will then shew him many things which his imagination before disregarded. New arrangements to be made, and unforeseen difficulties to be overcome, will infallibly present themselves. The first conception, or what the world calls the invention, required an infinitely small portion of the ability he must now exert. We will suppose, however, that he has completed his drawings. Still he possesses the form of a machine only; but whether it shall answer his purpose, depends on his knowledge of his materials. Stone, wood, brass, lead, iron forged or cast, and steel in all its various modifications,

difications, are before him; the general processes of the workshop, by which firmness, truth, and accuracy, are alone to be obtained; and those methods of treatment, chemical as well as mechanical, which the several articles demand:—these and numberless other practical objects call for that skill and attention, which may either lead to success, or, by their deficiency, expose him to the ignorance or obstinacy of his workmen. If he should find his powers deficient under a prospect so arduous—if he cannot submit to the severe discipline of seeing his plans reversed, and his hopes repeatedly deferred—if unsuccessful experiment should produce anguish without affording instruction, what will then remain for him to do? Will he embitter his life by directing his incessant efforts, his powers and resources, to a fascinating object, in which his difficulties daily increase; or will he make that strong exertion of candour and fortitude, which will lead him to abandon it at once?

"These are the inevitable stages of operation through which every inventor in mechanics must pass. To the mere habit of viewing objects in new lights, the habit which leads to the outline of invention, he must add the power of disposing his notions in the form of an individual engine or instrument; and he must himself become a workman, capable of discerning the means by which his ideas may become realized in the proper materials. It may perhaps seem as if I had selected an instance of difficulty, and indulged my imagination in a sketch of obstacles seldom likely to be met with. This, however, is far from being the case. Nothing seems more simple and easy at first sight, than to make an engine to cut notches in a piece of steel; and a very ingenious person, in the American Phil. Trans., has accordingly given an accurate design of an engine for that purpose, which no doubt he thinks must succeed. But manufacturers well know the value of such an engine, and have long ago attempted to make it by that and various other methods without success. That engine in particular, promising as it appears, is utterly incapable of working, for several reasons, scarcely to be discovered but by practical men, but which cannot with sufficient brevity be here detailed. And with regard to general obstacles in the detail of inventions, I am so far from magnifying them, that I am warranted by much experience, as well on my own behalf, as that of others whose plans and operations have come before me, to affirm, that no mechanical invention really new was ever brought to its complete or perfect state, at so small a charge as three times the cost of the finished engine, exclusive of the incalculable labour of the contriver." Phil. Journ. 4to.

Many useful tools have been invented for performing mechanical operations, which consist of a number of wedges or teeth, which may be conceived to stand upon, or rise out of a flat or curved metallic surface. When these teeth are formed on the edge of a plate, the instrument is called a saw, (see SAWING); but when they are formed upon a broad surface, it constitutes what is denominated a file. The comb-makers use a tool of this description, called a quonet, having coarse single teeth, to the number of about seven or eight to an inch. Fine tools of this description are called floats. When teeth are crossed they are called files; and when, instead of the notches standing in a right line, a number of single teeth are raised all over the surface, it is called a rasp. Files are cut upon the surface with a sharp-edged chisel. In rasps, the tooth is raised with a triangular punch. The file is adapted for working metals, but the rasp is more fitted for wood, bone, and horn. Files are distinguished by being single or double cut. The single cut file is simply cut once over, and is employed for filing brass, and the softer metals. A second course of teeth is cut to form the double cut file, crossing the first diagonally. This kind is best suited to iron and steel.

The steel employed for files requires to be very hard, and in consequence undergoes a longer process in the conversion (see STEEL). It is said to be double converted. The very heavy files, such as smith's rubbers, are made of the inferior marks of blistered steel: the more delicate kind, such as watch-makers' files, being made of cast steel. The steel is previously drawn at the tilt, into rods of suitable size. The flat and the square files are made wholly with the hammer, and the plain anvil. Two workmen, one called the maker and the other striker, are required in the forging of heavy files; the smaller being forged by one person only. The anvil is provided with a groove, for the reception of bosses or dies, which are used for the purpose of forging the half-round and three-angled files. The half-round boss contains a hollow which is the segment of a sphere, less than half a circle. That used for the triangular files has a hollow consisting of two sides, terminating in an angle at the bottom. In forging the half-round file, the steel is drawn out, as if intended to make a flat file. It is then laid in the die, and hammered, till the under side becomes round. The steel for the triangular file is tilted into square rods. The part to form the file is first drawn out with the hammer, as if intended to form a square file. It is then placed in the die with one of the angles downwards, and by striking upon the opposite angle, two sides of the square are formed into one, and consequently a three-sided figure produced. By successively presenting the different sides to the action of the hammer, the figure is rendered still more complete. In forming the tangs of most files, it is necessary to make the shoulders perfectly square and sharp. This is performed by cutting into the file a little on each side with a sharp instrument, and afterwards drawing out the part so marked off, to form the tang. After forging, and previous to being ground and cut, the files require to be annealed. This process is generally performed by piling up a great quantity together in a furnace for the purpose, and heating them red hot; suffering them afterwards to cool slowly. This method of annealing files, or indeed any other articles, in which great hardness is requisite, is very objectionable, since the surface of steel, when heated red-hot in

the open air, is so liable to oxydation. A superior method of annealing is practised by some file-makers, and since hardness in a file is so essential a property, the process ought to be generally adopted. This method consists in placing the files in an oven or trough, having a close cover, and filling up the interstices with sand. The fire is made to play on every side of the vessel, as gradually and as uniformly as possible, till the whole mass becomes red-hot. The fire is then discontinued, and the whole suffered to cool before the cover is removed from the trough. Another evil may however arise from keeping steel red-hot even in a close vessel, for too great a length of time. It assumes a kind of crystallization, under which its tenacity is much impaired. Steel annealed in this way, is perfectly free from that scaly surface acquired in the open air; and if each corticle be perfectly surrounded with the sand, and the cover not removed before the steel is cold, the surface will appear of a silvery white colour. If the steel be suspected to be too kind, from containing too little carbon, powdered charcoal may be employed instead of sand, or sand mixed with charcoal. In this case the files should be stratified alternately with the charcoal, in order that the extra-conversion may be uniform.

The next thing is to prepare the files for cutting, by making the surface to contain the teeth as level as possible. This was formerly effected by means of files, and the process is called striping. The same is still practised by the Lancashire file-makers, and by others not having convenience for grinding. The greatest quantity of files, however, are ground to prepare them for cutting. The stones employed for the purpose are of the sand-stone kind, the texture of which is compact and sharp, but rather rough. They are of as great diameter as can be used with convenience; and about eight inches broad over the face. When used, the surface is kept immersed in water. The grinder sits in such a position as to lean over the stone, while its motion is directly from him. Its surface moves at about the same speed with those used in grinding cutlery. Since the object in grinding files is to make the surface as even and flat as possible, and as this cannot be done so completely upon a small stone, the stones of the file-grinder are laid aside when they are reduced to a certain size, and are employed for grinding other articles. Though grinding is by far the most expeditious method, it does not give that truth to the surface which can be effected by filing. If the price of the articles would admit, however, it would be well to render the surface more even by the file after grinding. If the surface be not flat, it is obvious, that when the file is used for filing a large surface, those teeth in the hollow parts of the file will not be brought into action. It is from attention to this circumstance, and to the care in annealing and hardening, that the Lancashire file-makers have generally excelled. They are, however, confined chiefly to the small articles, since the larger files would not pay for the process of striping. The tools of the file-cutter consist of an anvil placed upon a block of such a height that the man sits to his work. He has also a piece of lead alloyed with tin, on which he lays the files when one side is cut. The chisel and hammer are of such size as the size and cut of the file require. He is also provided with a leathern strap, which goes over each end of the file and passes round his feet, which are introduced into the strap on each side in the same manner as stirrups are used. The file-cutter, therefore, sits as if he were on horseback, holding his chisel with one hand, his hammer in the other, at the same time he secures the file in its place by the pressure of his feet in the stirrups.

Great pains ought to be taken in preparing the edge of the chisel. It is, in the first place, hardened and tempered by heating it gradually till it appears of a yellowish brown. It is next ground very true to form the edge, which is afterwards finished upon a Turkey stone with oil. It is not required to be very sharp, the bottom of the tooth requiring to be rather open, to prevent the file from clogging with the substance to be filed. The edge is also required to be very smooth, in order that it may slip easily upon the surface of the files: this is also facilitated by slightly greasing the surface. From this advantage the worker, after making one tooth, is enabled by feeling only, to form at its proper distance the succeeding tooth, by sliding the chisel close up against the back of the preceding one.

In the double-cut files, the first set of teeth, which the workmen call up-cutting, are, previous to cutting the second course, filed slightly upon the face, in order to allow the chisel to slide freely. The single-cut file is more durable than the double-cut, and ought to be preferred for all purposes excepting for iron and steel. The same method is employed in cutting the rasp. The workman is, however, guided completely by his eye in regulating the distance of the teeth from each other. The rasp ought to be cut in such a manner that no one of the teeth may stand opposite to another; this not only allows the rasp to cut faster, but makes the surface either of wood or other substance much smoother.

The operation of simple file-cutting seems to be of such easy performance that it has for almost two centuries been a sort of desideratum to construct a machine to perform that, which is not only done with great facility by the hand, but with wonderful expedition. We are told that a lad not very much experienced in the business will produce, with his hammer and chisel, nearly three hundred teeth in a minute. With respect to machinery, it is said, that a Frenchman named Mathurin Jousse, in a work entitled "La fidelle Ouverture de l'Art de Serrurier," published at La Fleche, in Anjou, so long ago as the year 1627, gives a drawing and description of one, in which the file is drawn along by shifts by means of wheel-work, and the blow is given by a hammer. There are several machines of this kind, or at least to effect the same purpose in the "Machines Approuvées par l'Academie Royale de Paris:" there is also one published in the second volume of the Transactions of the American Philosophical Society, of which

which we shall give some account, as we shall of another for which Mr. William Nicholson obtained a patent in the year 1802; premising that the principal requisites in a machine for file-cutting, are that the metal from which it is manufactured should be steadily supported, and the chisel adapted to the face without any unequal bearing.

The American machine consists of a bench of well seasoned oak, and the face of it planed very smooth; and a carriage on which the files are laid, which moves along the face of the bench parallel to its sides, and carries the files gradually under the edge of the cutter or chisel while the teeth are cut. The carriage is made to move by a contrivance somewhat similar to that which carries the log against the saw of a saw-mill. The lever or arm, which carries the cutter, works on the centres of two screws which are fixed into two pillars in a direction right across the bench. By tightening or loosening these screws, the arm which carries the chisel may be made to work more or less steady. There is likewise a regulating-screw, by means of which the files may be made coarser or finer: also a bed of lead, which is let into a cavity formed in the body of the carriage, somewhat broader and longer than the largest-sized files; the upper face of this bed of lead is formed variously, so as to fit the different kinds of files which may be required.

When the file or files are laid in their place, the machine must be regulated by the screw to cut them of a due degree of fineness. This machine is described as being so simple, that when properly adjusted a blind person may cut a file with more exactness than can be done in the usual method with the keenest sight; for by striking with a hammer on the head of the cutter or chisel all the movements are set at work; and by repeating the stroke with the hammer, the files on one side will at length be cut; then they must be turned, and the operation repeated for cutting the other side. This machine may be made to work by water as readily as by hand, to cut coarse or fine, large or small files, or any number at a time: but it may be more particularly useful for cutting the very fine small files for watchmakers.

We shall now give an account of the machine, for which Mr. Nicholson obtained His Majesty's letters patent.

"My machinery," says the patentee, "consists in four essential parts, suitably constructed and combined together; namely, First, a carriage or apparatus, in or by which the file is fixed or held and moved along, for the purpose of receiving the successive strokes of a cutter or chisel. Secondly, the anvil, by which the file is supported beneath the part which receives the stroke. Thirdly, the regulating gear, by which the distance between stroke and stroke is determined and governed. And, fourthly, the apparatus for giving the stroke or cut. The four several parts are supported by, or attached to a frame or platform of solid and secure workmanship, either of wood or metal, or both, according to the nature of the work intended to be performed, and the judgment and choice of the engineer. The carriage is a long block of wood, or metal, of the figure of a parallelipidon, or nearly so, having a portion cut out between its upper and lower surfaces to admit the anvil to stand therein, without coming into contact with the carriage itself. The said carriage is made of such a length that the excavation here described shall be considerably longer than the longest files intended to be cut; and it is supported upon straight bearers from the platform, upon which by projecting pieces, or slides, or wheels, or friction-rollers, it can be moved endwise in a straight lined direction, without shake or deviation. At one end of the said excavation is fixed a clip resembling an hand-vice for holding the file by its tail or tang; and in the opposite end of the said excavation there is a sliding block or piece, which being brought up to the other end of the file does, by means of a notch or other obvious contrivance, prevent it from being moved sideways. The said clip is so fixed at its head or shank by means of an horizontal axis on gudgeons and sockets, that the file is at liberty to move up and down, but not sideways or a-twist. In this manner it is that the file being fixed in the carriage is pressed down upon the anvil by a lever and weight proceeding from the platform, and bearing upon the face of the file by a small roller of wood, ivory, bone, or soft metal. The anvil is solidly fixed on the platform, and may be of any suitable figure which shall be sufficiently massy to receive and resist the blow; but its upper part must be so contracted as to stand up in the excavation of the carriage and support the file; and the upper part of all must be constructed in such a manner that it shall fairly apply itself to the under surface of the file, and support it without leaving any hollow space, notwithstanding any casual irregularities of the said surface. I produce this effect by making a cavity in the anvil of the figure of a portion of a sphere, not much less than an hemisphere, and in this cavity I place (with grease between) a piece of iron or steel made exactly to fit, but of which the lower surface is a greater portion of the sphere, and the upper surface flat and plain. The file rests upon this last flat or plain surface, which is either faced with lead, or (in preference) a slip of lead is put under the file and turned round the tang thereof, so as to move along with it. It is evident that the upper or moveable piece of the said anvil will, by sliding in its socket, accommodate and apply itself constantly to the surface of the file, which is pressed and struck against it. Or, otherwise, I make the concavity in the upper moveable piece, and make the fixed part convex: or, otherwise, I support the upper part, or in some cases the whole of my anvil upon opposite gudgeons, in the manner of the gimbals of sea compasses: or, otherwise, I form the upper part of my anvil cylindrical, of a large diameter, supported on thick gudgeons, the axis of the said cylinder being short, and at right angles to the motion of the carriage: or, otherwise, I form only a small portion, namely, the upper extremity of my anvil of a cylindrical form as aforesaid, and cause the same to continue

tinue motionless by fashioning the same out of the same mass as the rest of the anvil, or fixing the same thereto. And in both the last-mentioned cases of the cylindrical structure I fix the head or shank of the clip (by which the tang is held), not by a single axis or pair of gudgeons, but by an universal joint or ball and socket, so that the file becomes at liberty to adapt itself not only upwards and downwards, but also in the way of rotation or a-twist, and supplies the want of motion in the anvil by the facility with which itself can be moved in the last-mentioned manner.

"The regulating-gear is that part of the machinery by which the carriage, and consequently the file is drawn along. It consists of a screw revolving between centres fixed to the platform, and acting upon a nut attached to the carriage with usual and well known precautions for working of measuring screws; and the nut being made to open by a joint when the carriage is required to be disengaged and slided back. And the said screw is moved either constantly by a slow motion from the first mover, or (which is better) by interrupted equal motions, so as to draw the carriage during the interval between stroke and stroke. And the quantities of those respective equal motions may be produced and governed at pleasure by wheel-work applied to the head of the screw, or by the well known apparatus used in the mathematical dividing engine for circles; or by various other contrivances well known to workmen of competent skill, and therefore unnecessary to be described at large: or, otherwise, the motion of the carriage may be produced by a toothed rack from the carriage drawn by a pinion; and this pinion moved by a ratchet-wheel on the same arbor moved by a click-lever, which shall gather up and drive a greater or less number of teeth, according to the coarseness or fineness of the file; and the click-lever itself may be moved by a tripping piece from the first mover, or by various other evident means of connexion: or, otherwise, the said carriage may be moved by a small cylinder, and rope or chain constantly acting: or, otherwise, the said motion may be effected by a train of two or more wheels, suffered to move by any of the escapements used in time-pieces, and the fineness of stroke may be regulated either by changing the wheels as in the common fuzee engine, or by the greater or less frequency of escape during each turn of the first mover. And in every case I prefer a counter-weight to the carriage, acting either constantly against, or constantly in the direction of its motion; though this is not absolutely necessary when the work is well executed. I may also observe, that it is possible to construct my said machinery by fixing and rendering motionless that part which I have called the carriage, provided the other three principal parts be made to move instead of the carriage itself; but I consider this disposition as less eligible than that which requires the carriage to be moved. The apparatus for giving the stroke or cut, consists of a chisel, which is held between the jaws of a mouth-piece or claws resembling a strong hand-vice without teeth. One of the jaws is made very stout, and the chisel is formed narrow from edge to back, and wide from side to side, and has a semi-circular protuberance on its back, which rests in a circular notch in the strong jaw aforesaid; and there are two or three bended flat rings or washers of iron or metal under the thumb-screw of the said mouth-piece or claws, which prevent the chisel from becoming loose by the stroke: or, otherwise, the said chisel may have a notch, or a hole, instead of a protuberance, to meet a correspondent part in the mouth-piece or claws; but I prefer the first-mentioned construction. By the construction of the chisel as here mentioned and fixed, the edge of the said instrument is at liberty to apply itself fairly from side to side of the file notwithstanding any winding or irregularity, whatever may be the fineness of the cut upon a broad surface. The mouth-piece, with its chisel, is firmly fixed in another piece, which by its motion gives the stroke. This last-mentioned piece may either be a lever or a moveable carriage between upright sliders; but I greatly prefer the lever. The chisel must be so fixed that the moving piece shall carry it fairly edge-onwards to the file without scraping or slapping in the least; and the obliquity of the stroke may be adjusted by fixing the centres of the level either higher or lower at pleasure, or by inclining the last-mentioned sliders. The lever may be raised and let fall (or the other chisel apparatus moved) by a tripping-piece or snail-work, or other usual connexion with the first mover; and its power of stroke may be increased by the addition of a weight, or by the action of a spring; which last method is of excellent use, and may (if required from the varying breadth of the file) be made to increase or diminish its power during the run by several easy and commonly used methods or contrivances for pressing more or less against the spring. Or, otherwise, the lever, or holding-piece, may be kept immediately above the file by the re-action of a slight spring, or weight, and be struck by an hammer moved and acted upon by the first mover, as aforesaid: and to this method I give the preference, because the lever will then have less strain upon its pivots; or, the said lever may even be supported by spring-joints without any pivots or centres at all. Or, instead of a hammer, the blow may be given by a ram, or a fly and screw, but I give the preference to the hammer. The lever may move in a vertical circle immediately over the file, or in an oblique circle at right angles to it, or at any intermediate angle consistent with the foregoing instructions: and the chisel may be set with its edge at any angle whatever, with the line of the length of the lever; but, in general, I have set the lever in the first-mentioned position, and have varied the angle between the chisel-edge and the lever, according to the intended slope of the cut upon the face of the file. The edge of the chisel must be sharpened to such an angle as the intended cut and strength of burr may require. Lastly, I describe the general action of the said machinery as follows: 1. The file being prepared as usual for cutting, must be fixed in the clip of the carriage, and the sliding-block brought up and fixed, to

to steady its other extremity. 2. The nut of the screw being then opened (or the other regulating gear disengaged,) the carriage is slided to its place, so that the chisel may be situated over that part of the file which is to receive the first stroke. 3. The nut is then closed (or the other regulating gear connected) and the small roller of the pressing lever is made to bear upon the face of the file. 4. The first mover being then put into action, raises and lets fall the apparatus for giving the stroke by which the file receives a cut. And, 5, immediately afterwards, or during the same action, as the case may be, (according to the construction as before described,) the regulating gear moves the carriage, and consequently the file, through a determinate space. 6. The cut is then again given; and in this manner (the strength of cut being duly proportioned to the space between cut and cut,) the file becomes cut throughout. 7. The file is then taken out and cut on the other side. 8. The burr is then taken off, or not, as the artist may think best; and the cross-strokes are given over the surfaces as before. And the said machinery, by certain slight, necessary, and obvious changes in the structure and disposition of the chisels, and some other of the parts thereof, is adapted to manufacture all other forms and descriptions of files, whether floats, rasps, half-round, three-square, or any other figure or denomination.

Three things are strictly to be observed in hardening files; first, to prepare the file on the surface, so as to prevent it from being oxydated by the atmosphere, when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough, that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult. The first object is accomplished by laying a substance upon the surface, which, when it fuses, forms as it were a varnish upon it, defending the metal from the action of the oxygen of the air. Formerly the process consisted in first coating the surface of the file with ale-grounds, and then covering it over with pulverised common salt. After this coating becomes dry, the files are heated red-hot, and hardened; afterwards, the surface is lightly brushed over with the dust of cokes, when it appears white and metallic, as if it had not been heated. This process has lately been improved, at least so far as relates to the economy of the salt, which, from the quantity used, and the increase of duty, had become a serious object. Those who use the improved method are now consuming about one-fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale-grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files only require to be dipped into this substance, and immediately heated and hardened. The grounds or the flour are of no other use than to give the mass consistence, and by that means, allowing a larger quantity of salt to be laid upon the surface. In this method, the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method, the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect. Some file-makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the effect very little. Animal carbon, when properly prepared and mixed with the above hardening composition, is capable of giving hardness to the surface even of an iron file. The carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoe-makers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal parts, by bulk, of this powder, and muriate of soda, be mixed together, and brought to the consistence of cream, by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it become of the above consistence. Files which are intended to be very hard, should be covered with this composition, previously to hardening. By this method, files made of iron, which in itself is insusceptible of hardening, acquires a superficial hardness sufficient to answer the purposes of any file whatever. Files of this kind may be bent into any form, and in consequence are rendered useful for sculptors and die-sinkers.

The mode of heating the file for hardening, is by means of a fire similar to that employed by common smiths. The file is to be held in a pair of tongs by the tang or tail, and introduced into the fire, consisting of very small cokes, pushing it more or less into the fire, for the sake of heating it regularly. When it is uniformly heated of a cherry colour, it is fit to quench in the water. An oven is commonly used for the larger kind of files, into which the blast of the bellows is directed, being open at one end for the purpose of introducing the files and the fuel. After the file is properly heated, for the purpose of hardening, it should be cooled as quickly as possible; this is usually done by quenching it in the coldest water. Clear spring water, free from animal and vegetable matter, is best calculated for the hardening files.

When files are properly hardened, they are brushed over with water and powdered coke, when the surface becomes clean and metallic. They may likewise be dipped into lime-water, and dried before the fire as rapidly as possible, after which they should be rubbed

over with olive oil, in which is mixed a little oil of turpentine while warm, and then they are finished.

In the operations of filing, the coarser cut files are always to be succeeded by the finer; and the general rule is, to lean heavy on the file in thrusting it forward, because the teeth of the file are made to cut forwards. But in drawing the file back again for a second stroke, it is to be lifted just above the work, to prevent its cutting as it comes back. The rough or coarse-toothed file, called a *rubber*, serves to take off the unevenness of the work, left by the hammer in forging. The bastard-toothed file, as it is technically called, is to take out too deep cuts and file-strokes made by the rough file. The fine-toothed files take out the cuts or file-strokes which the bastard file made, and the smooth file those left by the fine file.

FOUNDING.

The art of founding in metal, or casting it, now occupies a space in our wants which entitles it to considerable attention. If the Greeks, and after them the Romans, perfected it in as far as refers to casting in brass and bronze, we have extended it more than they did, inasmuch as we have turned it to all the great features of general utility. Iron constitutes the grand staple in modern founding. The great abundance of this metal, with its consequent cheapness, together with the developements of chemistry, has, amongst us, opened to it a field, and created for it a demand, by which its operations may go on ad infinitum, and it is hoped with a success commensurate.

Founding is as multiplied as there are metals susceptible of fusion by elevation of temperature; and as all those that are at present known are in some way or other so, it follows that all may be founded. In addition to which, it has now been shewn, that the earths (always considered as elements by the ancients) are metals, deprived only of their distinguishing characteristics by their excessive affinity to oxygen. Sir H. Davy, to whom these discoveries were left to be achieved, has demonstrated the fact, and numerous metals, or, as he has termed them, metaloids, have been added to the nomenclature of those previously known. How far his discoveries may be extended, it is impossible to conjecture: he has shewn that the calcareous earths, as well as potash and soda, are susceptible, by being exposed to high degrees of temperature, of changing their form, and flowing like melted silver, possessing all the distinguishing characteristics by which we determine a metallic substance. The French chemists have repeated his experiments, and confirmed his discoveries, from which a new epoch in science has arisen.*

* See Sir H. Davy's Papers, Philosophical Transactions, 1809, 10, 11.

Founding will be divided into its various and distinct branches, and will include founding in brass and bronze, iron in all its multiplied ways, also bell and type founding, with some observations on casting in the precious metals.

Brass is a compound of copper and zinc, but from the excessive volatility of the latter, it is difficult to ascertain the precise proportion it contains of each; but they become, by being fused together, a homogeneous malleable yellow metal, of great utility in supplying the medium to a beautiful and extensive manufacture of works in brass, required in our domestic economy, as well as a very important part in the arts, in which it is also employed in the founding of statues, &c. &c.

Founders in brass require an exact model, in wood or otherwise, of the article to be founded; and this is most frequently required to be in two parts, exactly joined together, and fitted by small pins, and the casting, in such a case, is performed by two operations, that is, one half at one time and one half at another, and in manner following, viz. The founder provides himself with a yellowish sharp sand, which is required to be well washed, to free it of all earthy and other particles. This sand is prepared for use by a process called tewing, which consists in working up the sand in a moist state, over a board about one foot square, which is placed over a box to receive what may fall over in the tewing. A roller about 2 feet long and 2 inches in diameter is employed in rolling the sand about until it is brought into that state which is deemed proper for its business: a long-bladed knife is also required to cut it in pieces. With the roller and the knife the tewing is finished for use, by being alternately rolled and cut. When the sand is so far prepared, the moulder provides himself with a table or board, which in size must be regulated by the castings about to be performed on it. The edges of the table or board are surrounded by a ledge, in order to support the tewed stuff; the table so previously

viously prepared is filled up with the sand as high as the top of the ledge, which is in a moderately moistened state, and which must be pressed closely down upon the table in every part. When the operation has so far advanced, the models must be all examined, to see that they are in a state to come nicely out of the mould, and if not found so, they must be cleaned or altered till the founder is satisfied with them. All models require the greatest accuracy in their making, or it will be vain to suppose any thing good can be performed by the founder. When the models are found to be in a state to be founded, one half, generally longitudinally, is taken first, and this is applied on the mould, and pressed down into the tewed stuff or sand, so as to leave its form completely indented in it, and which must be very carefully looked to and examined minutely, to see that there are no small holes, as every part in the indented sand must be a perfect cameo of the models submitted and pressed into it. If it should not be found perfect, new sand must be added, and the model re-indented and pressed into it, till it leaves its impression in a state proper to receive the metal. In the same manner, other models intended to be founded on the same table, must be prepared and indented into the sand. When the table is completely ready for the metal, it is carried away to the melter, who himself examines its state, and also the cameos, and who lays along the middle of the mould the half of a small wire of brass, which he presses into the sand, so as to form a small channel for the melted brass to flow in, and which he terms the master-jet or canal. It is so disposed as to meet the ledge on one side, and far enough to reach the last pattern on the other; from this is made several lesser jets or branches, extending themselves to each pattern on the table, and by which means the fluid metal is conveyed to all the different indented impressions required to be cast on the table. When the work is so far forwarded, it is deemed ready for the foundry; but previously to which, the whole is sprinkled over with mill-dust, and when it is so sprinkled, the table is placed in an oven of moderate temperature till it gets dry, or in a state which is deemed proper to receive the melted brass. The first table being thus far completed, it is either turned upside down and the moulds or patterns taken out, or the moulder begins to prepare another table exactly similar to the one he has just completed, in which he indents and presses the other half of the mould, or he turns the table already finished and containing the first half of the patterns upside down; previously, however, to doing which, it will be necessary for him to loosen the pattern which is fixed in the sand a little all round, with any small instrument that will just open away the sand from its edges, in order to its coming from out of the table more easily. This economy in founding, of making one half of each pattern to be cast answer the purpose of the whole pattern, is a very common practice in brass founding, and enables the manufacturer to sell his goods at a much cheaper rate than he would otherwise be enabled to do, if he was obliged to have a full pattern of all goods to be founded. When he has loosened the sand from about the pattern, and taken it out of the first table, the work is proceeded in, of preparing the counterpart or other half of the mould with the same pattern, or otherwise, and in a frame exactly corresponding with the former, excepting only that it is prepared with small pins, to enter holes which are made in the first half of the model, and into which the pins enter, and secure the two halves together. It is obvious, that the accuracy in the joining will depend wholly upon the neatness and truth of fixing and boring for the pins. When the table containing the counterpart is finished, the patterns are all properly indented in the sand, which is done as has been before described for the first table, and when completed, it is carried away to the melter, who, after enlarging the principal jet of the counterpart, and making the cross jets to the various patterns, and sprinkling them as before with mill-dust: it is then set in the oven till it has received a sufficient drying to be ready for the melted metal; after which, and when both parts of the model are deemed sufficiently dry, they are joined together by means of the pins and holes, previously prepared in the upper and under model: and to prevent their rising up or slipping aside by the force of the melted brass, which is to come in, flaming with heat, and through a small hole contrived in the principal or master jet, the precaution is taken of locking the two tables down in a kind of press made with screws; or, if the mould be too large to admit of being screwed easily, wedges are had recourse to, to fix the tables together, to prevent accidents. The moulds thus fixed in the press, or wedged, are placed near the furnace, and every arrangement is made for it to receive the melted brass as it comes out of the crucible.

All being so far arranged, and the moulds ready, the metal is prepared, by being heated to a complete fusion in an earthen crucible, commonly about 10 inches high and 4 inches in diameter. The furnace for promoting the fusion of the brass is similar to a smith's forge, having bellows of large dimensions operated upon by a lever, as well as a chimney over the furnace for the smoke to escape through. The hearth of the furnace is of masonry or brick-work, secured by an outer rim of iron, in the centre of which is the fire-place, and which consists in making a void or cavity, from 12 to 18 inches square, and reaching quite down to the bottom or floor of the foundry. The void or cavity is divided into two parts by an iron grating, on the upper side of which is placed the fuel, and in the midst of it the crucible containing the metal; the lower part of the cavity is appropriated to admit the air to the fire, and also to receive the waste or cinders falling from the fire. The fuel consists of dry beechen wood cut into small billets, and previously baked, to make them more readily combustible, and which are, when a fire is required, put into the cavity in the hearth, and well lighted. The crucible, when full of brass, should be placed down in the centre of the fire, so that it may play all round it, and

and it should be covered with an earthen cover, or tile, to promote the heat of the fire upon the metal. All the time the metal is preparing, the attendant keeps blowing up the fire; and in order to keep the heat from escaping through the chimney, or in flame, a piece of tile is placed over the fire and aperture of the furnace. As the heat operates in melting the metal, it sinks nearer to the bottom of the crucible, when fresh metal is added till the crucible is quite full. The brass is previously prepared for melting, by being broken into small fragments in a mortar, and when sufficiently beaten and broken for use, it is put into the crucible by an iron ladle, which has a long hollow arm or shank of small diameter, but sufficiently large to admit the fragments of metal rolling through it into the crucible, into which the fresh brass is dropped from out of the cylindrical arm of the iron ladle. As the crucible is filled with metal, preparation must be made, when it is deemed ready to be removed, for the purpose of running it into the moulds, to remove it easily from out of the fire, which is done by a pair of iron tongs with their feet bent inwards. The crucible is taken hold of by these tongs, and carried away to the mould, into which the melted brass is poured, through the aperture communicating to the master-jet of each mould; the metal is carried round to each jet, and the metal poured in till the crucible is emptied, or the moulds filled. It is usual to fuse rather more brass than is required for the casting; as by having too little, the work could not be at that time finished, which would occasion delays in opening the tables.

As soon as the moulds are run, water is sprinkled over the tables, to cool and fix the metal; after which the presses or wedges are removed from the frames, and the works just founded are removed out of the sand, to be cleaned and finished for sale. The tewing-stuff or sand is afterwards taken out of the frames to be worked up again for another casting. The sand, by a repetition of use, becomes quite black, by reason of the charcoal that it collects from the foundry; but its blackness does not render it unfit to be employed in other tables for moulding or casting.

In foundings of brass in which the models are large, an expedient is had recourse to, of rendering them lighter and more economical, by performing the casting hollow. This is done by making a core or heart, roughly resembling the pattern, and composed of clay and white crucible dust well kneaded and mixed together with water, and which is covered with wax, exactly representing the article to be cast; or the core may be suspended in the centre of the indents made in the sand. When the article is required to have but one perfect side, as is common in most cabinet articles, the melted metal, in such a case, is prevented from filling the indent by the space occupied by the core, and it will be in thickness corresponding to the size which the heart or core takes up, in proportion to the size of the work to be founded. In the former case, when the article is to have both or all round of a full pattern, wax is employed, and is so adjusted to the core, that the metal may, in passing the jet, displace it, and leave its resemblance, and also its thickness, of brass, in the indent in the table. If it be a pattern of a complicated form, there would arise a difficulty in getting the core out after it was founded. The pattern must then be performed or moulded in two separate ones, and also the foundings; the part left out of the first pattern must be performed in a second; and afterwards fitted and soldered to the first. This mode is common at Birmingham, in making handles for locks, and shutter fastenings, which are commonly round. The plain knobs, for locks, &c., are made in halves and soldered together: the wrought ones, as they are called, (from being ornamented) are cast with a solid shank and spindle, and the bell or handle part of the knob is hollow, and open at its opposite end, which is afterwards supplied by a separate piece or cap. The cores of many of these Birmingham brass-works are made to occupy so much of the pattern, that the brass is not thicker than a shilling.

Many of the brass-manufacturers who work on a large scale, employ a steam-engine to punch many of the articles from sheet metal, from dies previously formed. By this operation almost all the common brass goods, (such as hand-plates to doors, roses to door and cabinet furniture, and many light goods) are made. The punched goods are very cheap, but of very little strength or durability, as may be noticed in many of the brass articles employed in our domestic economy. Brass mouldings, plain or wrought, are generally cast solid, and in moderate lengths; a pattern in wood, clay, or wax, is required, and the only precautions previously to founding them are, that they be carefully indented in the sand-table. If the mouldings be large and much carved, a core may be used for these also, taking care to leave the metal sufficiently thick to allow of finishing up afterwards, without injuring the effect of the pattern.

All brass, as well as other foundings, require, when taken out of the sand, to be cleaned up and made complete; as they seldom come out exactly perfect. This is done in brass-founding, by filing off the cores, and filling up the small holes with melted metal or solder. These imperfections frequently occur by air-bubbles, which are generated by the heat of the metal. Some brass-works are cast to a rough pattern, for instance, all those which are cylindrical in shape; and such kind of goods are put into a lathe and turned, and smoothed up afterwards (See our article TURNING). Articles in brass which are sculptured, are generally left in a mat-state on their grounds, and the raised parts burnished up by hand; the mat-state refers to such parts only which are left without polish, or in a state in which the brass is found when it first comes out of the sand, with the addition of cleaning and perfecting only.

The burnishing consists in making the raised parts quite complete, and afterwards laying them down tight upon a bench, or in a vice, whichever is most convenient;

nient; and working up the face of the brass with a bent tool composed of a shaft of steel, about half an inch wide and eight or nine inches in length, fixed firmly in an handle of wood. The end of the tool is turned up about a quarter of an inch, and ground away on its inner edge. With this tool the workmen rub the part to be *heightened*, as it is termed. They have these heightening tools of various widths, some one-eighth of an inch wide only, and others as much as three-quarters of an inch. With such tools they operate upon all the various sized parts to be heightened; and as the part is thus rubbed, the workman dips his tool in a lacquer, which is standing near him in an earthen-ware dish. This lacquer is commonly prepared from turmeric dissolved in spirits of wine, and which will be afterwards explained under the head of lacquering.

Chasing, or enchasing as it is called, is also employed to brass works. It is a similar operation to heightening, except that it is employed in the more delicate works of sculpture to give them greater sharpness and effect. The French excel in chasing, as their numerous small ornaments used as decorations to chimney-pieces, time-pieces, vases, &c. &c., fully demonstrate; many of which are in brass as well as in d'or molu.

Brass castings which are plain are cleaned up for sale by being filed smooth or turned so by the turner, and afterwards polished by being rubbed with emery till the surface becomes regular and tolerably even, after which they are finished with tripoli. To keep brass works from tarnishing and getting black by exposure to the air, the brass-workers have recourse to lacquering. Lacquering consists in covering the brass, moderately heated over a stove containing an open charcoal fire, with a liquid, also moderately warm, composed of saffron and Spanish annotta, each two drams put into a bottle with a pint of highly rectified spirits of wine, which when together should be placed in a moderate heat and often shaken, from this a very strong tincture will be obtained, which must be afterwards strained through a coarse linen cloth to take out the dregs of the annotta and saffron; it is then to be returned to the bottle, and three ounces of seed-lac powdered must be added to it, and the whole again heated till the seed-lac be completely dissolved; after which it is fit for use, and will form a good and pale-coloured lacquer, which will prevent the brass from changing colour by exposure to the air. It is laid on the brass by a camel's-hair pencil as thin as it can be spread, and requires nothing to be done to it after it is so spread but a moderate rubbing. If the brass be required to be of a redder colour, increase the proportion of annotta in the lacquer, and it will be accomplished. All the best kind of brass-works are gilt to prevent their changing colour, and this constitutes the desideratum in the works in d'or molu.

The more important part of casting in brass consists in founding statues, busts, basso-relievos, vases, &c. The Greeks and Romans practised it to an immense extent, as may be seen from the vast number of statues and other works which have come down to us of both these people. The Greeks also formed most of their instruments of brass, which we make of iron and steel. Homer describes most of the arms in his poems, offensive and defensive, as brazen. He calls the Greeks by the general epithet of brass-coated, and seldom mentions steel. In Herculaneum, Pompeia, Stabea, &c. were found many arms and instruments formed of brass or bronze, while very few of iron were discovered. Those of brass were adapted to the purposes of agriculture, mechanics, mathematics, architecture, &c. In Pompeia was found a complete set of surgeons' instruments formed of bronze, which shews that a preference was given to that metal.

In the founding of statues, busts, &c., three things in particular require attention: namely, the mould, the wax, and shell or coat, the inner mould or core, so called from being in the middle or heart of the statue. In preparing the core the moulder is required to give it the attitude and contour of the figure intended to be founded. The use of the core is to support the wax and shell, to lessen the weight and save the metal. The core is made and raised on an iron grate sufficiently strong to sustain it, and it is farther strengthened by bars or ribs of iron. The core is made of strong potter's-clay tempered with water, and mixed up with horse-dung and hair, all kneaded and incorporated together; with this it is modelled and fashioned previously to the sculptors laying over it the wax; some moulders use plaster of Paris and sifted brick-dust mixed together with water for their cores. The iron bars which support the core are so adjusted that they can be taken from out of the figure after it is founded, and the holes are restored by solder, &c.; but it is necessary in full sized figures to leave some of the iron bars affixed to the core to steady its projecting parts. After the core is finished and got tolerably firm and dry, the operation of laying on the waxen covering to represent the figure is performed, which must be all done, wrought and fashioned by the sculptor himself, and by him adjusted to the core. Some sculptors work the wax separately, and afterwards dispose and arrange it on the ribs of iron, filling up the void spaces in the middle afterwards with liquid plaster and brick-dust, by which plan the core is made as, or in proportion to, the sculptor's progress in working the wax-model. Care must be taken, however, in modelling the wax in both cases to make it of an uniform substance, in order to the metal being so in the work, of which the wax is its previous representative. When the waxen model is finished to the core, or adapted and filled afterwards, small tubes of wax are fixed perpendicularly to it from top to bottom, to serve not only as jets to convey the melted metal to all parts of the work, but as vent-holes to allow a passage to the air generated by the heated brass in flowing into the mould, and which if not admitted readily to escape would occasion so much disorder in it as would much injure the beauty of the work. Sculptors adjust the weight of the metal required in this kind of founding by the wax taken up in the model. One

pound of wax so employed will require ten pounds of metal to occupy its space in the casting. The work having advanced in progress so far will now require covering with a shell. This consists of a kind of coat or crust laid over the wax, which being of a soft nature easily takes and preserves the impression which it afterwards communicates to the metal upon its occupying the place of the wax, which is between the shell and core. The shell is composed of clay and white crucible dust well ground, screened, and mixed up with water to the consistence of paint, like which it is used. The moulder applies it by laying it over the wax with a camel's-hair or other soft pencil, which will require eight or nine times going over, allowing it time to dry between each successive coat. After this coating is firm upon the wax, and which is used only to protect it from those which are to follow, the second part or coating is made up of common earth mixed with horse-dung: this is spread all over the model, and in such thickness as to withstand in some measure the weight of the intended metal. To this coating or impression is added a third, composed almost wholly of dung, with a proportion of earth sufficient only to render it a little more tough and firm when used. When this is tolerably dry, the shell is finished by laying on several more coats or impressions of the same composition, made strong and stiff by successive workings with the hand. When this is finished and is deemed adequate to support the heated metal, it is farther secured and strengthened by several bands or hoops of iron, bound round it at about six inches from each other, and fastened at bottom to the grate on which the statue stands. Above the head of the statue is made an iron circle for the purpose also of confining the shell and statue, to this circle the hoops are fastened at top. It may be considered when the moulding is arrived at this state to be in a condition to receive the melted metal; but it is not so exactly as will soon appear. The mould, as has been before observed, is made upon an iron grate: under this grate is a furnace and flue, in which at this period of the work a moderate fire is to be made, and the aperture of communication therewith stopped up so as to keep in the heat. As the heat increases and begins to operate upon the mould, preparation must be made to allow of the wax running freely from out of the shell: for this purpose pipes are contrived at the base of the mould, so that it may run gently off and through these pipes. As soon as it is all run off, the pipes are nicely stopped up with earth to prevent the air entering them, &c. When this is done, the shell is surrounded by any matter that has non-conducting properties, for instance, pieces of brick put round and piled up of good thickness, secured by earth, will answer the end; and the whole should be finally coated outside with loam as a farther protection to keep in the heat.

After the shell is adequately surrounded with materials to keep off the effect of the air, the fire in the furnace is augmented till such time as both the matter surrounding the shell and it also become red-hot, and which in ordinary circumstances will take place in twenty-four hours' time; the fire is then extinguished and the whole allowed to cool: after which the matter which has been packed round the shell is taken away, and its place occupied with earth moistened and closely pressed to the mould in order to make it more firm and steady. It will, when having advanced so far, be in a state to receive the melted metal; to prepare which for the casting, a furnace is made a few feet above the one employed to heat the mould: it is formed like an oven having three apertures, one of which is for a vent, the other to admit the fuel, and the last to let the melted metal flow through and out of the furnace. This last aperture should be kept very close whilst the metal is fusing, when it has arrived at that state which is deemed proper for running it into the shell, and which is known by the quick separation and escape of the zinc of the brass. A little tube is laid to convey it into an earthen-ware bason, which is fixed up over the top of the mould. Into this bason all the large branches from the jets enter, and from which is conveyed the metal into all the parts of the mould. The jets are all stopped up with a kind of plugs, which are kept close till the bason which is to supply the metal be full. When the furnace is first opened for this purpose, the melted brass gushes forward like a torrent of fire, and is prevented from entering any of the jets by the plugs, till the bason is sufficiently full to be ready to begin with the mould, and which is esteemed so when the brass it contains is adequate to the supply of all the jets at once, upon which occasion the plugs from all of them are withdrawn. The plugs consist of a long iron rod, with a head at one end capable of filling the whole diameter of each tube. The hole in the furnace in which the melted metal is contained is opened with a long piece of iron fitted on the end of a pole to allow of the furnace-man keeping at a distance from it, as many accidents occur by the red-hot metal coming in contact with the air, particularly if it be damp, in which case the most violent explosions take place. The bason is filled almost in an instant after the furnace-plug is withdrawn, and the metal is then let into the several jets communicating with the model, which when they have emptied themselves into the shell or mould the founding is finished, in as far as the casting is concerned. The rest of the work is completed by the sculptor, who takes the new brass figure from out of the mould and earth in which it was encompassed, saws off the jets, and repairs and restores the parts where required. His tools for this purpose consist of chisels of various sizes, gravers, puncheons, files, &c.

In casting colossal statues a somewhat different mode is pursued than the one already described, and this arises wholly from the size, it being found difficult to remove the moulds of such colossal works; to obviate this difficulty, it is worked and prepared upon the spot where it is to be cast. There are two ways of performing this, and some founders prefer the one and some the other. By the first plan a square hole is dug

dug into the earth somewhat larger than would be required for the mould, and its sides are hemmed up with brick-work: at its bottom is formed a hole below the bottom of the one already prepared, as a furnace, and which must be built up with brick-work, having an aperture made outwards into another pit prepared near it, from which the fuel is put into the furnace. The top of the furnace in the first hole is covered by a grating of iron, and on this is moulded and placed the case of the statue to be cast, and also its waxen coating; in doing which the same process is observed by the sculptor as that already described. Near the edge of the large pit in which the model is placed is erected the furnace to melt the metal, and which is similar to the one already described for common figure-casting, except being of larger dimensions; it has like that three apertures, one for putting in the wood, another for vent, and a third to run the metal out at. By the second plan of founding colossal figures, it is thought sufficient to work the mould above ground, adopting the same mode with respect to a furnace and grate underneath it. For, whether under ground or above it, to keep in the heat when drying the core and melting the wax, is that which is more particularly sought for; to do which in the most effectual way four walls of brick-work are built up round the model, in the middle of which is fixed the grate and furnace; and on one side above is formed the mass of building intended for the furnace, which is to be appropriated to the melting of the metal. When the whole is finished and ready, a fire is made in the fire-place under the core of the model, and kept up so as to produce a moderate heat to dry the core, and also to melt away the wax from off it, which runs down by tubes as has been before remarked upon, and indeed no difference whatever takes place in such founding, except every thing being on a larger scale. When the wax is run off and the fire extinguished in the furnace, bricks are filled in at random, either into the hole, if founding under ground, or into the area between the walls if above ground; after this is done the fire in the furnace is again lighted, and blown up and augmented till such time as both the core and bricks are of a red-heat, when the fire is again extinguished and the whole is left to cool; and when cooled the bricks are removed and all is cleared away, and the space again occupied by moistened earth to secure and steady the model. Nothing now remains but running in the metal, which is performed as has been before described for smaller foundings of statues.

The casting figures in brass is not much practised among the moderns at this time, although it was a good deal followed at the restoration of the arts in the 15th century. At that time brass-works were had recourse to in the decoration of most buildings of any consideration, and in order to supply the metal at little cost, several of the ancient edifices then existing were mutilated for the purpose. In Rome many of the vaultings to the temples were ornamented by having their lacunaria relieved by pateras and other decorations of brass or silver; these the popes of the times removed to compose the childish ornaments for their then erecting or newly consecrated Catholic churches. France, Germany, and England, at that time subject to the same caprice in religion as well as in the arts, adopted a similar style of decoration in their religious edifices, as numerous reliques still existing in tombs, shrines, screens, and other parts of their cathedrals and religious houses fully demonstrate. Amongst us certainly, and particularly after Henry the Eighth's separation from the church of Rome, such works were discontinued as catholic and idolatrous. Elizabeth, proceeding in the reformation already commenced by her predecessor, not only destroyed the images but the pictures also, and at the same time strictly forbad any thing of the kind to be admitted in future under the severest penalties. The rebellion in 1648 completed what the reformation had begun. The fanatics of this time defaced whatever they could get at, that the former inquisition had spared; they tore down the brass from the monuments and screens, carried away the plate from the altars, broke the painted windows, and dilapidated the tombs of the saints, crying out in their work of spoliation "cursed be he that doth the work of the Lord deceitfully." After this it would be vain to look in England for works in brass of any consideration, as little was spared but what was too remote for the Vandals of these reigns to get at. From this time among us a void or chaos existed and continued to exist in works of art, till a more enlightened policy began to unbend itself, which happened about the middle of the seventeenth century. But the effects of the persecution had been felt so much that the liberal arts had lost their practisers from the terror of the times, hence the introduction of foreigners to do that which we had been forbidden to practise, and the consequent notion about our inability in works of taste, which is much too insipid and ridiculous at this time to need refutation.

All the principal cities of ancient Greece and Rome boasted of their wealth by enumerating their statues of brass. Athens, Delphos, and Rhodes are each reported to have had in and about their temples 3,000 brass statues. And Marcus Scaurus, though an edile only, adorned the Circus at Rome with upwards of that number of statues of brass, during the time of the celebrating of the Circension Shows. It afterwards, in consequence of this taste continuing to prevail at Rome, of forming and collecting works in brass, used to be a proverb among the visitors of that celebrated city, "that in Rome the people of brass were not less numerous than the Roman people."

It now remains to treat of a much more recent application of brass than has hitherto fell under our notice, and which, if considered in its effects, is calculated to be equally striking, if not of displaying equal intelligence with those parts of the founding of brass already described. The founding of pieces of brass-artillery, including

cluding cannon, mortars, &c. &c., was the common practice after the invention of gunpowder first took place. It is true the art of founding iron was then known, but not so well understood as it was soon afterwards, and is at present. In consequence of the ignorance of the chemical properties incident to iron, all the first cannon cast of it were not found capable, when adequately charged, of projecting balls without being shivered in pieces; by reason of which brass was employed in artillery, and is partially continued to be used to the present period. As to the metal it is somewhat different to that which is made use of for statues and other works of brass, inasmuch as it contains a proportion of tin, which is not found in them. A cannon is always cast in its shape somewhat conical, or more properly of the frustum of a cone; it has the thickest metal at the breech, in consequence of the greatest effort of the gunpowder being there; it diminishes from thence to the muzzle, and is so proportioned the one to the other, that if the mouth be determined to be two inches, the breech is made six inches: with respect to the length it is measured among artillerymen by calibers taken at the muzzle of the gun. They say, according to a proportion previously determined, that one caliber in diameter of six inches at the muzzle requires a length of twenty calibers to be given to the gun; or if the diameter of the bore be six inches, the shaft or depth of it will be ten feet. In apportioning the ball to the caliber, about one-sixth of play is allowed it.

The composition of the brass of which cannon is formed is somewhat different in different countries; the proportion with us is, to 10 lbs. of tin we add 100 lbs. of copper; whereas in the brass of statues zinc is employed instead of tin. However, the respective quantities of different metals that should enter into the composition of brass ordnance is not so decided as to be given with mathematical accuracy. The usual proportions are to 240 lbs. of metal deemed fit for casting, or which has been previously cast, are put 68 lbs. of copper, 25 lbs. of common brass, and 12 lbs. of tin. The Germans, who are fond of brass ordnance, prepared as follows; viz. to 4,200 lbs. of metal fit to cast again, they add $3,687\frac{33}{47}$ lbs. of copper, $204\frac{13}{47}$ lbs. of brass, and $307\frac{30}{47}$ lbs. of tin. The French are reported to use in their brass for guns the proportions of 100 lbs. of copper to 6 lbs. of common brass and 9 lbs. of tin, and this proportion is sometimes varied by others to 100 lbs. of copper, 10 lbs. of common brass, and 15 lbs. of tin. All cannon, &c. are cast solid, and their insides bored out afterwards; and this is effected by means of a machine invented at Strasburgh, and continued to be used till very lately at all the depots for founding ordnance. The gun to be bored by this machine was placed in a vertical position, which was turned or put in motion by a windmill, horse, &c. This mode is now laid aside in a great measure, and instead of the gun being raised vertically it is laid down horizontally, and the boring goes on by means of steam or some other power. The instrument employed in both ways is nearly similar, excepting the change of its position. It is so contrived that while the boring is advancing the outside is cleaning and polishing; hence the gun is finished all to its carriage at the same time.

The casting of guns is performed as has been already described for statues, &c., excepting only no core is required, it being cast solid; the shell-wax, furnace, &c., are alike in both processes, and enlarged in proportion to the size and quantity of the casting required to be made.

Bronze, or by the Italians Bronzo, was well known to the ancients. Egyptians, Greeks, and Romans all made use of it, and that in most cases to their important works as connected with sculpture and the ornamental parts of architecture. Bronze was selected by these people as bearing a finer edge, and not so likely as either of its component parts to oxydate by exposure to the air: hence they made statues of it to adorn the approaches to their cities and public edifices, affixed it in beautiful and highly relieved ornaments to the friezes of their temples, cast it in basso-relievos to represent the paraphernalia of their games and festivals, which were retained in compartments about their works dedicated to their gods; and, finally, wrought it into baths, tripods, vases, lamps, and other purposes of utility and ornament; specimens of many of which have by its instructibility come down to us, as may be seen exhibited in the numerous public galleries on the Continent, at Rome, Naples, Florence, and Paris, with some in our own Museum.

The Egyptian bronze consisted, according to Basari, of two-thirds brass and one-third copper. Pliny says, "the Grecian bronze was formed by adding one-tenth lead, and one-twentieth silver, to the two-thirds brass and the one-third copper of the Egyptian bronze," and this was the proportion afterwards made use of by the Roman statuaries. The Greek bronzes very obviously appear to possess a difference of composition to any that have been founded among the moderns. The famous horses (four in number), said to have been the work of Lysippus, which now adorn the approaches of the palace of the Thuilleries at Paris, having been brought there, as a trophy of the victories of its present emperor Napoleon, from Venice, exhibit at once, to bronzists, that the ancient metal of that name was, in its composition, very different from that which is now made and called after that designation:—the modern bronze is commonly made of two-thirds copper, fused with one-third of brass; and very lately, from the great demand for all kinds of ornaments in this metal, in forming the decorative parts to our apartments, and supports to our articles of furniture, lead, with zinc in small proportions, have been added to the copper and brass. These variations have been one cause of the greater brilliancy and compactness to be observed in modern castings of this metal, in comparison of those founded a few years since. So common is bronze-work become at this time, that every petty brass-worker pretends to be an adept in founding of this metal; however, nothing is to be

be feared in the attempt, as the efforts of such bronzists will not carry them beyond the work of the furnace.

The alloying of the several metals to form bronze is found to promote in it a readier fusibility than is possessed by either of its component parts in their pure metallic state; and this is a property very much to its advantage in the castings of large works. Modern works in bronze become numerous in proportion to the advancement in the arts. Bronze-casting is employed in forming equestrian statues, colossal and other figures in alto-relievo, to set-off and adorn public places. It is competent, when in the hand of an artist, of giving a zest to architecture; inasmuch as by its tint, as well as by the great variety of the forms it is susceptible of being made into, it is able to add richness by its opposition, and at the same time it finishes the forms of those parts of architecture requiring it.

Bronze casting is performed in the following manner, viz. 1. The figure or pattern to be cast must have a mould, and this is prepared and laid on a plaster cast, previously wrought and finished by the sculptor. The mould is made of plaster of Paris, rendered moist by being mixed up with water; to this preparation is added brick-dust, in the proportion of one-third of the former to two-thirds of the latter. This is carefully laid on the mould, with strength in proportion to the weight of metal intended to be used in the founding. In its joints small channels should be cut tending upwards, and from different parts of the internal hollow, to allow of vent for the air to escape through, as the heated metal runs in upon the mould. A thin layer of clay should be spread over the inside of it, and of the thickness which it is intended the bronze should be. Within-side of the clay, a filling up of plaster and brick-dust, in the proportions as before described, will be required to compose the core: but if the work to be cast be large, before the plaster and brick-dust are poured into the mould to form the core, a skeleton composed of iron bars, as a support for the figure, should be prepared and fixed; after which, the filling up of the core may be proceeded in. When this is done, the mould must be opened again, and the layer of clay taken out of it, and the core thoroughly dried, and even burned with a charcoal fire, or with straw; for if the least damp remain, the cast will be blown to pieces when the hot-metal comes in contact with it, in running it into the mould, and the workmen employed about the work be maimed or killed by the dispersion of the heated bronze. After the core, &c., has been properly dried, and is deemed ready for the work, it should be laid in the mould, and supported in its place by short rods of bronze, which should run through the mould into the core. All being so far advanced, the mould should be clad and bound round with iron, of strength proportionate to the size of the work to be cast; after which, the mould should be laid in a situation for running in the metal, and must be supported for the purpose, by bricks, &c. Great care should be taken that every part be perfectly dried, before any metal be run into the mould; or, as has been before observed, the most fatal consequences will arise to those who may be about the work. A channel must be made from the furnace in which the melted metal is, in order to its running to the principal jet of the mould, and with a descent, to promote its flowing rapidly. The jets, furnace, &c. &c., are all contrived as has been before described for casting figures in brass.

In Vesaris's Lives, is a chapter on brass-founding; and there is also some very useful observations in the Life of Bevenuto Cellini, vide Pliny's Natural History.

The smaller works in bronze are founded by previously being modelled in wax, to which a coating of clay is adapted and dried (See *Brass Casting*).

Bronze works are cleaned up and repaired after being founded, in a similar manner to which figures in brass are, and with the same kind of tools; but this last touch of perfecting what may have been left imperfect by the mould, should invariably be done by the statuary or modeller himself; as no one is so competent to keep up the spirit of the original work, as he who invented it, and gave effect to his invention, by making the model.

The principal works executed in London in bronze, claiming particular notice, are, the equestrian statue at Charing Cross, of Charles the First; the colossal statue of his present Majesty, together with the basso-relievos, and other insignia, in the square of Somerset Place, executed by the late Mr. Bacon. The statue of Francis, duke of Bedford, with the attributes of agriculture on the pedestal, to the promoting of which he had devoted his time and fortune: this work has been very recently placed, on the south-side of Russell Square, and was executed by Mr. R. Westmacott. The last public work of bronze is the equestrian statue of William III., erected in the centre of St. James's Square, and is the work of Mr. J. Bacon, Jun. There are also many bronzes of great merit in the provinces; and there are many more at this time under execution at our sculptors. Mr. Flaxman, who is called "the Phidias of the moderns," is now executing a statue of the late Sir John Moore, K. B., who was unfortunately killed at the ever-memorable battle of Corunna. This work is calculated, from its superiority in design and chasteness of style and execution, to establish the sculptor's genius on principles as imperishable as the metal is from which the work has been wrought. It is intended to be raised at Edinburgh when complete, and it will be so in a few months.

The founding of iron, if it be considered in how multiplied a way it is now employed, makes it occupy a space in the public economy of very great importance, and that of an infinitely superior description to any of the other discoveries which have already been made as appertaining to the arts.

Cast-iron is now employed (in addition to what it has been hitherto, and which is too well known to be recited) in the formation of bridges of great extent; in roofs, and the girders and joists in buildings, as well as the

the sash-frames and sashes. It has also been used with success in wheels and other machinery to our steam-engines, and also for their cylinders. It is founded hollow, in the form of columns, partaking of the three known designations in architecture; and has been lately used to compose the immense mains, and branches from them, to our public water-works. The facility of casting it, with its consequent cheapness, has been a means of creating a trade for it to our trans-atlantic friends, which, until the interruption of that amity which has now so long subsisted, was excessively profitable. Birmingham and its neighbourhood is the great entrepôt for works of all kinds in iron. Here are the furnaces which supply the world with the goods wrought to every device required for the people's comfort, accommodation, ease, or luxury. Tram or rail-roads have founded their success in the application and facility of casting their rails of iron. Canal works are largely concerned in promoting iron founding, as by these the labour attending making them has been much abridged, and its details rendered more secure and permanent. It supplies the modern means of war, by facilitating the formation of artillery of every description, and that in a better and more improved manner, than had hitherto been done by the other means had recourse to for that purpose. And it is daily arriving at so improved a state, that it will not be too much to say, "that in a few years cast-iron will be the desideratum in architecture, engineering, and the arts."

A foundry of iron is, when calculated to do business on a large scale, situated near, and connected with, the ore and the blast furnaces, as here it is that the ore-smelting is done; and where that is performed, castings can be executed better, and much more cheap, than when it is done at separate establishments; it is also better done, because, as more metal is heated at a time at such furnaces, there is a better chance of getting the castings perfect. It is cheaper, from this very obvious circumstance, that as the new metal is smelted, it is at once cast into the work required, instead of being run into pigs, as they are termed, to be re-heated in another furnace, and then to be founded. This additional heating, with the cost of removal and labour, is saved by founding it into what is required at its first being smelted.

The foundry, or place in which the furnaces are placed, is a building of oblong shape, surrounded by walls of masonry or brick-work, of a single story in height, and its size is determined by the extent of the business proposed to be done in it. At the Carron or Charron Iron Works, in Scotland, there are many such buildings all connected to one grand establishment. There are also several in Derbyshire: but those of the most considerable importance are in Staffordshire, at Colebrooke-dale, Willenhall, &c. In London there are many extensive works of this description, and where they do many things on a large scale; and these are mostly situated at Lambeth. Wherever a foundry is to be formed, a dry situation should be selected for it; as dampness would totally prevent any thing being cast with tolerable accuracy, besides rendering the founding, in such places, dangerous to the workmen employed. The floor of a building for this business should be about 10 feet deep, and composed of a kind of loamy-sand; and if the place selected does not afford this convenience naturally, the ground must be excavated, and such sand brought to fill up the excavation. This loamy sand is for the purpose of burying large moulds beneath its surface, so that the metal may be conveyed to them by channels or soughs hollowed out of the sand, and through which it runs from the furnace to the mould to be cast. A foundry, or casting-house, is provided with as many air or reverberating furnaces, in addition to the blast furnaces, as is required for the extent of the works to be founded at it. An air or reverberating furnace is only used occasionally, either when the metal contained in the blast furnace is not sufficient, or when the quality made in it is not proper for the work about to be cast. The difference in the qualities of the metals arise from their containing too much or too little carbon; and this is corrected by the founder, by mixing them with better or worse metal, *till* they are rendered fit for the purpose required. Cupolas are also wanted in a foundry, as they are called, and are similar to the blast furnace, except being of somewhat smaller capacity: they are used to melt small quantities of metal, when it is wanted in haste; as the reverberatory or blast furnaces will take more time in filling the charge of metal than the cupola does, by reason of their being of larger capacity; but the founding by cupolas requires more machinery, from which circumstance it is not so well adapted to answer the purpose of the founder, as founding with a reverberatory or blast furnace is. A much greater stock of flasks and other implements are wanted to make the moulds with, than are required by the caster who performs his work by means of either of the other furnaces. These kind of furnaces are always in use at large foundrys, as at these places can be employed the whole charge of metal they are capable of containing.

In the foundry, by a blast furnace, a pit is sunk at a convenient distance from the furnace, and the moulds for all large articles, such as pipes, &c., are placed vertically in it, within reach of the crane, that they may be raised or lowered in the pit. The metal is conveyed from the furnace by a gutter or sough, made in the floor of the foundry, and a small iron trough filled with sand conducts the fluid metal into the moulds. This method of performing foundings to large works, is an improvement on the old one, (which consisted in burying the pattern in sand,) and which has caused a great saving in labour and time. The flasks for this method of casting are founded of iron. It is now a practice, at most of our large foundrys, to substitute sand for loam castings, in cases in which there are a great number of articles of the same kind to be cast; so that the expense of the flasks becomes an object of no great importance. When it happens that the articles are intricate, the sand

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is wetted so much as to render it sufficiently adhesive to make it mould, and receive the form of the pattern completely; after this is done, it is necessary to dry the mould, to prevent accidents by the explosion of the hot-metal, when running the cast. For this purpose, stoves are used, in which an equal and moderate degree of temperature is produced, and of a capacity adequate to contain a good number of the patterns. The moulds, when ready to be dried, are placed upon a carriage adapted to the purpose, and on which they are arranged and conveyed to the oven; and when dry, which generally happens in about half an hour, they are withdrawn, and a new set placed upon the carriage. Every foundry should be provided with one or more cranes, so placed as to be easily got at when it is required to raise or lower any large piece of casting; they should also have a boring-mill, for clearing out and forming the internal surface of all hollow casting, such as pipes, cylinders for steam-engines, &c. &c.; and the same machinery which turns the large lathes for this purpose, is also employed in the turnings of heavy mill-axes, pistons. the rollers in sugar mills, and the lamellating of iron, called "laminating rollers;" it gives motion to all these at the same time, and also blows the cupolas. At the foundrys in which the blast furnace is employed, this operation is supplied by a small pipe from the great blowing engine of the furnace.

The moulding of large pieces of casting which are required to be hollow, is made in loam, and consists in laying down an iron ring upon the ground, of the diameter of the proposed caliber of the work to be cast, and which has a rod of iron in its centre; after this is done, bricks, clay, and wet-loam, are mixed together, and built up within the ring, and round the iron rod, of somewhat less diameter than the cylinder about to be cast, and for which this is to form the core. The whole, when built, is bound round with iron hoops to protect it, and a fire is made in it to dry it, and when properly dried, a coating of loam is spread over it, and smoothed; this coat fills up, and makes it the proper size for the inside of the cylinder, and is called the core of the mould. Another cylinder is built and plastered in the same manner, but without hoops, whose diameter is the same as the outside of the cylinder to be founded. When this is finished, it is covered over with charcoal-dust, or charcoal ground, which is mixed up with water, like paint, and laid on with a brush; and a thin coating of loam mixed up with hair is then laid over the charcoal previously spread upon the inner cylinder. When all these are quite dry, a man gets into the cylinder, and with a picker pulls away from the core the bricks, and then with a trowel cuts away also the loam, leaving the inside of the external cylinder, which is called the mould, quite smooth. This part of the work is effected by the coat of charcoal, which prevents the two coats of loam from adhering together. While this is doing, a deep pit is dug, and into this the core is let down by a crane, and when down, the mould is lowered down over it, and when adjusted in its place, sand is thrown in and rammed round about it, to about the half of its height; after which a flat cover of dried loam is put on the top of the mould and core, and pieces of rounded wood are put into the holes which had been before made for pouring in the metal. The plugs which keep open these holes are carefully taken out, and small channels prepared for the metal to run through from the furnace. Before the metal is run into the mould, it may be necessary to observe, that it must be perfectly well dried, and every part of the mould examined, to see that it be in a proper state to receive the metal. Sand or open casting is used for such articles as will allow of cutting into two pieces, or even more, the models of which are indented in the sand, and the metal is run in between flasks.

As to the prices charged for castings in iron, they are regulated by the nature of the article required to be founded. At the smelting furnace, work of a large size is cast at little more than the price of the pigs, and this addition is created only by the moulding. Iron roofing to buildings, composed of all the detail of principal and other rafters, modelled, fitted, and put up complete, has been agreed to be done for the writer of this article after the rate of 11s. per cwt., founded at Birmingham and erected in the centre of London, and this price is to embrace the whole expense of the carriage and labour to raise it up and fix it completely on the building for which it is intended. The water pipes for the Grand Junction Company were founded at Colebrooke-Dale, and at a much less price than those above recited for the roofing. In London, cast iron work is more than treble the price which is charged for it at Birmingham, The founders in London will have from 17s. to 23s. per hundred for the larger piping, and as to the roofing it is doubtful if they could do it all, at any rate they would not do it for double the price. Gallery, or balcony railing, is founded generally in pannels of about five feet in length, and charged by the hundred as other foundings are; such goods are always cast in open sand; they are charged in London at from 28s. to 33s. per hundred weight, if the pattern be troublesome or difficult a greater price would be required for it; and this last estimate for cast iron founding, will be a very good ratio on which calculations may be made for castings in London. But the great foundrys in the country are the places at which things on a large scale should be had from, if economy be at all to be considered.

The manufacture of artillery, when of iron, was not, at first, conducted by casting it. Bars were so adjusted together, and bound by hoops, as to render them capable of withstanding the charge of powder and the projection of ball; but to do this, they were obliged to be excessively large, and consequently became so ponderous, as in some measure to be unmanageable. The casting of them was then had recourse to, and it was usual to do that hollow; from which circumstance, and from founding being in its infancy, many accidents occurred by the metal not being always adequate to withstand a powerful charge, or a repetition of it. Hence, founding artillery

artillery solid, and boring its inside out afterwards, was adopted, as the most likely method to avoid these inconveniencies, and which having been more successful than hollow casting, cannon have continued to be so cast ever since, with such other improvements as have gradually developed themselves.

It is generally believed that cannon have been made use of in Europe ever since the year 1338, and that they were employed for naval purposes, in the Baltic Sea, in 1350; at any rate, it is certain they were used by the Venetians in 1366, at the siege of Claudia Jessa. Larrey ascribes the invention of brass cannon to J. Owen; he asserts, there were none such known in England till the year 1535, and that iron cannon were, for the first time, cast in it in 1547. Specimens of great guns, as they were first used, and before the casting of them in foundrys came into use, are still to be seen in many parts of Europe, and some also in the Tower of London, and at Woolwich. They were, at first, called bombardes, and afterwards cannon. It was usual, formerly, to designate those which had been made uncommonly large, or had been supposed to have performed any uncommon service, by a particular name; accordingly, Louis the Twelfth, in 1503, had 12 brass cannon cast of extraordinary size, called after the 12 peers of France; the Spaniards and Portuguese named theirs after their saints. The emperor Charles the Vth, when he went against Tunis, had 12 cannon founded, which he called "the twelve Apostles." At Milan there is a 70 pounder called "the Pimontelli;" and there is one at Bois-le-Duc called "the Devil." At Dover Castle there is a 60 pounder called "Queen Elizabeth's Pocket-Pistol;" there is an 80 pounder at Berlin, called "the Thunderer;" two 60 pounders at Bremen, called "the Messengers of Bad News;" and there is one at Rome, made of the nails which fastened the copper and bronze ornaments about the portico of the Pantheon, with this inscription on it, "Ex clavis trabalibus porticus Agrippæ." At present, cannon take their names from the weight of the balls which they are intended to discharge: thus, a piece that discharges a ball of 24lbs. is called a 24 pounder, and that which takes a ball of 12lbs. a 12 pounder, and so on. Guns for ships consist of the following weights, viz. of 42, 36, 24, 18, 12, 9, 6, and 3 pounders. Garrison guns are of 42, 32, 24, 18, 12, 9, and 6 pounders. Battering guns are of 24, 18, and 12 pounders. Field pieces consist of 12, 9, 6, 3, 2, 1, and ½ pounders.

In addition to the artillery already named, there are mortars, howitzers, &c. &c. A mortar is a sort of cannon, with a short shaft, a large bore, and chamber. Mortars are thought to be the first pieces of artillery that were used, as they were employed for the purpose of throwing red-hot balls and stones. Mortars are also made use of for throwing hollow balls and shells filled with powder, in sufficient quantity to burst them. The ingenious Desaguliers contrived a method of throwing bags from them, filled each with from four to six hundred shot of different dimensions, and with adequate success. The effect of such an application must be awful and tremendous. Mortars are distinguished by artillery-men, by the diameter of their bores; hence a mortar with a bore of thirteen inches is called a 13 inch mortar, and one of eight inches, an 8 inch mortar, and so on. The sizes, lengths, and every detail and particular connected with the proportions of artillery, are settled and arranged by tables issued from the Board of Ordnance; and no piece of artillery can be made use of, unless conformable to the table published by its sanction. For a full description of all the various guns, their calibers and size of the metal, &c., allowed to be made for the use of the state, and also those which are used by the French, since the year 1793, when the table of their guns received many alterations, consult article Cannon, Dr. Rees's Cyclopedia.

The founding of artillery is conducted in a similar manner to other foundings in iron. The gun intended to be cast is moulded in the sand, from a model previously formed either in wood or clay. When the mould is complete and ready for the metal, it is suffered to run through a channel or gutter into the mould. The smaller guns are moulded on tables, and one half of the mould is formed in one table, and its counterpart or other half in another table. The counterpart is fitted to the first half by means of small pins which keep the two firmly together, and when so adjusted they are put under a heavy weight or into screws, to keep them from separating while the hot metal is running in to fill the model.

Till about forty years ago a cannon was cast with a cylindrical cavity, having nearly the same diameter with the intended caliber of the piece, and was afterwards enlarged and cleaned out by a machine adapted to the purpose. It consisted of two vertical bars of cast-iron from eight to ten feet in height, or in proportion to the gun to be bored, and confined by being screwed with nuts and screws to four cross-beams of the same metal, between which an iron frame was adjusted, composed of two upright pieces fitted parallel to the vertical bars and framed to three cross rails, into which is fitted the drill for boring out the gun. On their edges are eight small pieces of iron, projecting so much as to clasp the vertical-bars and to form a groove to keep the frame steady in sliding down while drilling out the inside of the cannon. In the centre of the upright frame is placed the gun to be bored out, with its small end downwards, and held to the frame by three bands of iron which are screwed to trunnions or fixed round it, one of which is placed at the breech, another in the middle, and the last at its muzzle: these bands are placed to prevent the gun from turning round by the action of the drill bar. At the bottom under the gun and drill, is placed a copper or iron pan of a circular shape, about twelve inches in diameter, with a projecting rim of about two inches in height for receiving the chips of metal separated from the piece while its inside is cleaning out. At the top of the sliding-frame are fixed large hooks, to which are looped, by iron loops, two

two three-wheeled block pulleys with lines, for the purpose of raising and lowering the cannon upon the drill. The drill bar is turned or moved round by a horse or horses, and the gun is kept to the work by its own weight pressing upon the head of the drill.

The drill bar is provided with a piece of iron rather larger than the diameter of the bore of the gun, and fixed upon the shaft of the drill to prevent it entering too far into the piece. This machine is now nearly out of use for boring and cleaning out artillery, as they are now invariably founded solid, and the drilling is performed in a different manner. The reason of discontinuing to cast guns hollow arose from the uncertainty of getting them sound by that way of founding. Cannon cast hollow were always more or less spongy, and numerous cavities were formed round the cores, which could not be removed by the drilling. Guns, or indeed any other founding required to be left hollow in their insides, must be moulded on a core or heart, and which is previously explained in the casting of brass and bronze. Some of the cavities left in the cores of guns by the hollow founding, were often found to be so deep that the boring would not take them out; and from this reason, and the uncertainty of the work being fitted to its intended purpose, solid casting was had recourse to and adopted at every foundry; since which time a new kind of machine for the purpose of boring out their insides has been invented and used, and which consists chiefly in the difference of placing the gun. By the first method the cannon to be drilled was suspended in a vertical frame as has just been described, whereas the gun is now laid down horizontally. The machine is somewhat different in its details in every establishment for gun-work, and experience can only determine which is the best. The one at the Garrat iron-works is found well adapted to answer the purpose; and there is also a very elaborate one at Woolwich, as well as at the Carron or Charon works in the North. The machine at Garrat consists of a long frame composed of ledgers of iron laid down on the ground, of length adequate to receive guns of any dimension; it is raised upon cross ledgers of wood to about two feet from the ground, having four upright shafts to support the gun, and also the drill for boring it. The drill bar rests on a block which is fitted near the muzzle of the gun, the other end of it is supported by a small carriage, which has wheels by which it is moved on the ledgers of the frame. To the bottom of the carriage is fixed an iron rack which works into a pinion, the rack is employed to move forward or backward the gun while under the operation of boring. It is kept steady to the pinion by a roller, and on the end of its axis a capstan head is fixed with holes in it to receive one end of an iron bar fixed to the side of the frame, while the other end is loaded with a weight for the purpose of advancing the borer into the gun, and is shifted as the boring proceeds, and this is known by the weight suspended at its end falling to the ground. After the guns are bored and their inside cleaned out, and their outsides turned to the shape desired, their touch-holes are to be drilled, which is done by an instrument mounted in a frame of wood; and which has at one end for the convenience of removing easily when it is to be used, wheels, and on this the frame is moved close to the gun requiring its touch-hole to be made. The cannon is laid on two blocks of wood of sufficient height to raise the wheels off the ground, which will prevent its running back while the hole is making. The drill, with its bow for turning it round, is then to be fixed between the touch-hole of the gun and the block. The block is advanced forward by using the arm of a bent lever, which is assisted by the means of a weight suspended on its opposite arm. On a beam over the machine is fixed a screw, the lower end of which is hollow for a few inches to receive one end of the drill, and on its other end is fixed a wheel or head to act as a fly to the upper part of the bore. To the shaft of the drill, two strings of catgut are fastened and twisted with their opposite ends tied to a handle, which operates by being twisted backwards and forwards, and with the motion of the bore in forming the touch-hole to the gun.

Cannon are always cast with a large cap at their muzzle, this originally was cut off with a saw, but now a machine is used for the purpose which a man works by a turning lathe; and as the turning goes on, the turner uses a chisel, with which he cuts into the gun to about one and a half inch deep. The cap so cut is broken off by being hammered.

Bells follow next in order. The æra of their invention is somewhat obscure, as we find no traces by which we can discover whether they were known to the ancients or not. It is not improbable but that they came into use at the spreading of the Christian religion, as some notices respecting them may be traced as early as the seventh century;* but they were at this time very small, and, it is probable, used only on particular occasions, and erected in cupolas. However, in the tenth century large ones became common, about the middle of which we find several of the churches were furnished with them by the munificence of our kings; and the account we have of St. Dunstan's gifts to Malmsbury abbey, plainly shews they were not very common among us in that age, for he says, "the liberality of that prelate consisted chiefly in doing such things as were then wonderful and strange in England, among which he reckons the large bells and organs which he gave them, and from this time they became more frequent, and afterwards the common furniture to churches. Bells no doubt at first suggested the necessity of towers. Towers promised to the imagination something noble and extraordinary in the uncommon effects they were capable of producing by their requisite loftiness and variety of forms. The Chinese have long been distinguished by their partiality for bells, and some of theirs are of large dimensions. There are also very

* Bede. Hist. lib. 4. cap. 22.

large bells in almost every cathedral on the Continent, besides many in England.

The manner of casting bells is similar to that of statues, except that the metal is different, there being in bell-metal about one-fifth of tin, whereas there is no tin in the brass of statues. The dimensions of the core and wax in modelling a bell, if it be to be one of a ring of several, must be formed on a kind of scale or diapason, which will give the height, aperture, and thickness of the shell necessary to the several tones required. The exterior of the bell is formed into rings fashioned into mouldings, and sometimes inscriptions, mottos, and figures are also added to adorn and set off its outside; all these are previously modelled and afterwards moulded in wax upon the core. The clapper or tongue is not properly a part of the bell, and is furnished by other hands: with us it is usually of iron, and is suspended in the middle of the bell. The Chinese make it of wood, leaving a hole under the cannon of the bell to increase its sound. Our proportions of bells consist in making the diameter fifteen times as thick as the brim, and its length twelve times. The bell itself consists of its sounding bow, which is terminated by an inferior circle, which diminishes thinner and thinner as it approaches to the brim or that part on which the clapper strikes, and which is required to be left rather thicker than the rest both above and below; also the outward sinking or properly the waist of the bell, or the point under which it grows wider to the brim and the upper vase, or top or dome of the bell, or that part which is above the waist. The pallet is the inside of the vase or dome to which the clapper is suspended. The vent and hollowed branches of metal which unite with the cannon to receive the iron-keys by which the bell is hung to its beam of support, where it must be exactly counterpoised. The height of a bell is in proportion to its diameter as twelve is to fifteen, or in the proportion of the fundamental sound to its third major, from which it follows that the sound of a bell is principally composed of the sound of its extremity or brim as a fundamental of the sound of the crown, and which is an octave to it, and that of the height, which is a third.

To mould a bell for casting, the following preparations must be made. Earth must be collected, and that which is most cohesive is the best, and it must be well ground and sifted. Brick or stone must be gotten for the mine, with which it must be steined. Horse-dung, hair, and hemp, must be mixed with the earth, to render the composition for moulding more firm and binding. The wax to mould the inscriptions, coats of arms, and other insignia about the outer surface of the bell: also tallow must be mixed with the wax in equal proportions, to make it mould more freely; which when mixed, a slight layer of it is put upon the model or outer mould, previously to any of the ornaments being applied to it. A scaffold is raised upon tressels round the mine, upon which is placed the earth grossly diluted with water, to make it mix better with the dung; and, last of all, shelves are to be placed, on which the models, &c., of the different ornaments or inscriptions to be cast upon the bell are put. A hole is now to be dug of an adequate depth to contain the mould of the bell, together with the case of it, or cannon, under ground, and about six inches below the level of the ground of the foundry. It must be wide enough to allow of a free passage between the mould and walls, or between one mould and another when several bells are to be cast. At the centre of the hole a stake is erected, which is fixed firmly in the ground; this supports an iron peg, on which the pivot of the second branch of the compasses of construction turns, (these compasses are the chief instruments for making the mould, and consist of two legs joined to a third at its apex). The stake is surrounded by solid brickwork, of about six inches in height and of the diameter of the bell; this is called the mill-stone. The parts of the mould consist of the core, the model of the bell, and the shell. When the outer surface of the core is formed, it is raised up with bricks, which are laid in courses of equal height upon a layer of earth; as each brick is laid the work is brought near to the branch of the compasses on which the curve of the core is shaped, so as that there may remain between it and the curve the distance of a line, to be afterwards filled up with layers of cement. The building of the core is continued to the top, leaving only an opening for the coals to be put in to bake the core. This work is covered with a layer of cement made of earth and horse-dung, and on which is moved the compass of construction, to make it of an even smoothness every where. Having finished the first layer in this way, the fire is put into the core by filling it half with coals through an opening kept shut during the baking, and with a cake of earth which has been separately baked. The first fire consumes the stake, and it is left in the core a half and sometimes a whole day: the first layer having become thoroughly dry, it is covered with a second, also a third and fourth, each being surrounded with a board and also the compasses, and also thoroughly dried before another is proceeded on. The core being thus finished, the compasses are taken to pieces with the intention of cutting away the thickness of the model, which when done they are again put in their places to begin another piece of the mould. This piece consists of a mixture of earth and hair applied with the hand upon the core in several cakes, these all close together if properly applied. This part of the work is finished afterwards in several additional layers of cement of the same matter smoothed by the compasses, and thoroughly dried before another is laid on. The first layer of the model is a mixture of wax and tallow, which is spread over the whole. When the work has so far proceeded, the inscriptions or other insignia intended to be cast upon the bell are applied, for doing which a pencil is used dipped in a vessel of wax melted in a chafing dish; this is done for every letter, or figure intended to be upon the bell. Before the shell is begun, the compasses are taken to pieces, in order to cut away all the wood that fills the place of the thickness which

which is intended to be given to the shell. When this is done and all is clear, the shell is begun, the first layer of which is the same earth sifted very fine. While it is tempering with water, it is mixed up with cow-hair to make it cohere; the whole, being a third cullis, is gently poured on the model, and fills exactly all the sinuosities of the figures, and this is repeated till the whole is two lines in thickness upon the model; when these layers are properly dried they cover it with a second of the same matter, but somewhat thicker than those previously laid on; the compasses are now tried, and a fire is lighted in the core, so as to melt off the wax of the inscription, &c.; after which the layers of the shell are proceeded in by means of the compasses. There is now to be added to the composition a quantity of hemp, which is spread upon the layers and afterwards smoothed upon the board of the compasses. The shell varies from four to five inches lower than the mill-stone before observed, but surrounds it quite close, and prevents the extravasation of the metal. The wax should be taken out before melting the metal. The case of the bell requires a separate work, which is done during the drying of the several incrustations of the cements. It has seven rings; the last is called the bridge, and united to the others, it being a perpendicular support to strengthen the curves. It has an aperture at its top to admit an iron peg and bent at its bottom, and this is introduced into two holes in the beam fastened with two strong iron keys. The rings are modelled with masses of beaten earth, that are dried in the fire in order to have them hollow. The rings are gently pressed upon a layer of earth, and cow-hair to about one-half of their depth and then taken out, and care should be taken not to break the mould. This operation is repeated twelve times for twelve half moulds, that is, two and two united make the hollow of the six rings; the same is done for the hollow of the bridge. They are all united together upon the open place left for the coals to be put into the oven. The rings which are to form the ears are put first into this open place, with the iron ring to support the clapper of the bell. After which a round cake of clay is made to fill up the diameter of the thickness of the core. This cake after having been baked is placed upon the opening, and fastened by a thin mortar spread over it, which binds the cover close to the core. The hollow of the mould is filled with an earth sufficiently moist to fix itself on the place which is strewed at several times upon the cover of the core; it is then beaten gently with a pestle, and afterwards smoothed by a workman at top with a wooden trowel dipped in water. Upon this cover, which is afterwards to be taken off, is assembled the hollow of the rings; and when every thing is in its proper place, the outside of the hollows are strengthened with mortar, in order to bind them to the bridge and keep them steady, and at the bottom by means of a cake of the same mortar, and which fills up the whole aperture of the shell. This is left to dry, that it may afterwards be removed without breaking. To make room for the heated metal, the rings are taken out of the hollows in the mould, as it is in these hollows that the metal is to pass as it enters into the voids in the mould. The shell being thus unloaded of its rings, the mill-stone is arranged by having placed under it five or six pieces of wood of about two feet long, and thick enough to reach almost to the lower part of the shell; between these and the mould wooden wedges are driven, in order to shake the shell from off the model, so as to be pulled away and removed up out of the pit. When this and the wax are removed, the model and layer of earth are arranged for the founding, as it is through these the melted metal must pass into the hollows made by the rings, and which are between the shell and core. The inside of the shell is last of all dried by burning straw under it, this helps to smooth the surface of the bell. The shell is put in the place so as to leave the same interval between it and the core as was before; and before the hollows of the rings on the cap are put on again two vents are made, which are united to the rings, and also to each other, by a mass of baked cement; after which this mass of the cap is put on, the rings and thevent over the bell are soldered to the cap by cement; which is dried by gradual heat by covering it with burning coals. So much having been done, the pit surrounding the whole is filled up with earth, being pressed strongly all the time of putting in close round the mould.

The furnace has a place for the fire and another to contain the metal; the fire-place has a large chimney with a spacious ash-hole. The furnace which contains the metal is vaulted, and its bottom is made of earth rammed down, the rest is built of brick-work. It has four apertures, the first of which admits the flame projected by the fire to reverberate, the second is closed by a stopple, which is opened for the metal to run through; the other two are to separate the dross and scoriæ by allowing the attendant of the furnace to introduce a wooden rake through it for the purpose. These apertures also pass the thick smoke. The ground or floor of the furnace is built sloping for the metal to run down. When the metal is fused and ready to fill the shell, which should be examined minutely in every part to see if it be dry and ready to receive it; when all is deemed ready, the metal is suffered to run into the shell by the apertures prepared to admit it, after which it is allowed to fix and cool. It is then taken out, examined, and cleaned, in a similar manner to what has been before explained for brass and bronze castings. The sound of a bell is said to arise from the vibrations of its parts much like that of a musical chord. The stroke of the clapper, it is evident, must change its figure, which if round make it oval; but the metal having a degree of elasticity, that part which the stroke drives farthest from the centre will fly back again, and this even for a time somewhat nearer the centre than it was before, so that the two points which before were the extremes of the longer diameter now become those of the shorter; thus the circumference of the bell undergoes alternate changes of figure, and by that means

gives

gives that tremulous motion to the air of which sound consists. M. Perault remarks, " that the sound of the same bell or chord is a compound of the sound of the several parts, so that were the parts homogeneous and the dimensions of the figure uniform, there would be such a perfect mixture of all their sounds as constitutes one uniform, smooth and even sound, and the contrary circumstances produce harshness. This he proves from the bell differing in time according to the part which is striken, and yet strike it any where there is a motion of all the parts. He therefore considers bells as composed of an infinite number of rings, which according to the different dimensions have different tones, as chords of different lengths have, and when struck the vibrating parts immediately stricken determine the tone; being supported by a sufficient number of consonant tones in the other part. M. Hawksbee has found that the sound of a bell stricken under water is one-fourth deeper than when in the air, though Mersunnus says, " it is the same pitch in both states." Bells are observed to be heard farther when suspended in plains than on hills, and still farther in valleys than on plains—the reason of which it will not be difficult to assign, if it be considered that the higher the sonorous body is the rarer is its medium, consequently the less impulse it receives, and the less proper vehicle it has to convey it to adistance.

Bells have been cast of enormous dimensions, and nations seem in some measure to have vied with one another on this subject. The Continent abounds with large bells. In China also there are many of uncommon proportions, and we have among ourselves several, but the largest in the world is at Moscow, buried in a swamp from its weight, having overset the tower in which it was suspended. Clark, in his travels, says, the numberless bells of Moscow continue to ring during the whole Easter week tinkling and tolling without any harmony or order. The large bell near the cathedral is only used on important occasions, and yields the finest and most solemn tone I ever heard. When it sounds, a deep and hollow murmur vibrates all over Moscow, like the fullest and lowest tones of a vast organ, or the rolling of distant thunder. This bell is suspended in a tower called the Belfry of St. Isan, beneath others which though of less size are enormous. It is forty feet nine inches in circumference, sixteen inches and a half thick, and it weighs more than fifty-seven tons. The great bell of Moscow, known to be the largest ever founded, is in a deep pit in the midst of the Kremlin. The history of its fall is a fable, and as writers continue to copy each other the story continues to be propagated. The fact is the bell remains in the place where it was originally cast; it never was *suspended*. The Russians might as well attempt to suspend a first-rate line of battle ship with all its guns and stores. A fire took place in the Kremlin, the flames of which caught the building erected over the pit in which the bell yet remained; in consequence of this the metal became hot, and water thrown to extinguish the fire fell upon the bell, causing the fracture which has taken place. It reaches from the bottom of the cave where it lays to the roof. The entrance to the cave is by a trap-door placed even with the surface of the earth. We (Messrs. Clark and Cripps) found the steps very dangerous, some of them were wanting and others broken, which occasioned me a severe fall down to the extent of the whole first flight, and a narrow escape for my life in not being dashed upon the bell. In consequence of this accident a sentinel was stationed afterwards at the trap-door, to prevent people becoming victims to their curiosity. He might have been as well employed in mending the steps, as in waiting all day to say they were broken. The bell is truly a mountain of metal; they relate that it contains a very large proportion of gold and silver; for that while it was in fusion, the nobles and the people cast in as votive offerings their plate and money. It is permitted to doubt the truth of traditionary tales, particularly in Russia, where people are much disposed to relate what they have heard without once reflecting on its probability. I endeavoured in vain to assay a small part. The natives regard it with superstitious veneration, and they would not allow even a grain to be filed off; at the same time it may be said the compound has a white shining appearance unlike bell-metal in general. And perhaps its silvery appearance has strengthened, if not given rise to a conjecture respecting the richness of its materials. On festival days the peasants visit the bell as they would a church, considering it an act of devotion; and they cross themselves as they descend and ascend the steps leading to the bell. The bottom of the pit is covered by water, mud, and large pieces of timber, which, added to the darkness, render it always an unpleasant and unwholesome place, in addition to the danger arising from the steps which lead to the bottom. I went frequently there in order to ascertain the dimensions of the bell with exactness. To my great surprise, during one of those visits half a dozen Russian officers whom I found in the pit, agreed to assist me in the admeasurement: it so nearly agreed with the account published by Jonas Hanway that the difference is not worth notice: this is somewhat remarkable, considering the difficulty of exactly measuring what is partly buried in the earth, and the circumference of which is not entire. No one, I believe, has yet ascertained the size of the lower rim of the bell, which would afford still greater dimensions than those we obtained, but it is entirely buried in the earth; about ten persons were present when I admeasured the part which remains exposed to observation; we applied a strong cord close to the metal in all parts of its periphery, and round the lower part where it touched the ground, taking care at the same time not to stretch the cord. From the piece of the bell broken off, it was ascertained that we had thus measured within two feet of its lower extremity. The circumference obtained was sixty-seven feet five inches, which allows a diameter of twenty-two feet five inches and one-third. We then took the perpendicular height from the top of the bell, and found it correspond exactly

exactly with the statement made by J. Hanway, viz. twenty-one feet four inches and a half. In the stoutest part, that in which it should have received the blow of the clapper its thickness equalled twenty-three inches: we were enabled to ascertain this by placing our hands under water where the fracture had taken place, which is about seven feet high from the top of the bell. The weight of this enormous mass of metal has been computed to be 443,772lbs., which if valued at 3s. per pound, amounts to 66,565l. 16s. lying unemployed and of no use to any one *. It is reported to have been cast during the reign of the Empress Anne.

The founding of Types is so nearly allied to printing that it is almost impossible to trace the former through its progress without saying something of the latter: they are together the noblest invention that was ever achieved by man, whether if considered as adapted to meliorate our condition, or elevate us to that rank as intellectual beings for which we were intended by our Creator.—Printing has pre-eminently contributed to promote this.—It has also humanized our nature by turning the mind to higher enjoyments than those to be derived by mere animal exertion.—By printing, as connected with rational governments, public liberty has been secured, and its maxims taught through its facilities. What the ancient orators did by frequently addressing the people, we do by a much more compendious mode, viz. through the Liberty of the Press. Through printing many have been found to be oracles, which but for it would never have been known, and consequently society would have lost the talents of some of its most brilliant members. Printing cannot be thought too much of; its importance is so obvious and necessary, that if one thing is more likely than another to keep off an age of darkness from ever again surrounding us it will be printing.—If the ancient nations had been enabled to print, the multitude would have been more enlightened. Hence there would have been more equality, and the power of dazzling by words, allowed to the few, must have stood the test of being examined as things, a privilege belonging to the moderns derived alone from printing. The progress of philosophy is entirely owing to the facilities in this art, in as much as it has registered its advances in a medium always to be consulted, and of course always open to be improved. The arts, religion, and law are dependent upon it; a large library is an epitome at once exhibiting the joint labours of genius;—here the reflecting mind may estimate, and that truly, the importance of type-making and also printing, because in it are to be found registered by their joint aid the powers of man, however directed.

The invention of types is supposed to have taken place at Mentz, about the beginning of the fourteenth century. They were first formed of beechen-wood, which not being calculated for much wear were soon laid aside, and improved by being cut in metal. Laurentius had the honour of this latter invention: however the cut-metal types were tedious in making, hence they were soon succeeded by founding. Theodosius Martin brought some of these latter kind of types into Holland from Strasbourg in 1472, and many books were there printed with them. From this time, and from Holland being a country of great resort for foreigners, they were exported from thence to most of the principal towns in Europe. In 1490 they were sent to Constantinople, by the middle of the next century to Africa and America, and to Russia in 1560; but from motives either of policy or superstition they were there destroyed as soon as their powers were made known. The first types used in England were at Oxford about the middle of the fourteenth century. Thomas Bouchier petitioned Henry VI. for this purpose, who granted his petition, and a press was put up at Oxford, worked by types brought from Holland. Caxton, who had been much in the Low Countries and Holland, had studied and made himself fully master of the business of using types, and when he came back to England established printing-presses: and as Caxton's books were more numerous than Bouchier's, to him generally has been given the honour of introducing printing in England. Caxton's press began to work in 1471, at least nothing was done by him before that date is known; whereas there is a book still at Cambridge with the date of its impression from Bouchier's press at Oxford, anno 1468. The existence of this book has robbed Caxton of the glory he had long possessed of being the author of printing in this kingdom.

From this time may be dated the power of England: those who thought it no distinction to be able to read before, now became ashamed at seeing a book containing that which formed the motive to conversation among a few priests beyond their ability to understand: hence the introduction of schools and seminaries, some of which were established by the royal authority.—To be able to read was the first effort, for very few were so at this time. As the rudiments of education became improved, books were multiplied and printing encouraged; and this progress has been gradually developing itself up to the present period. But a few centuries ago, so great was the distinction given to those who were enabled to read, that an education was supposed to be finished by having accomplished it; to write also was by no means thought necessary, and was left to be done by a very few. The education of the women was much neglected until within the last century; as knowledge was thought to be necessary only to the men.

But for the cutting of types and printing, Europe might have remained to be governed by popes and cardinals: by their means alone the politics of such governors were exhibited, known, and execrated. Types continued to be cast with very few improvements, excepting those which have arisen from out of the change in the shape of the letters, till the beginning of the seventeenth century. Wm. Caslon set up a foundry for types

* It is not improbable but this may be corrected by the present inhabitants of the Kremlin and of Moscow. The French are too expert at removals, and too eager for plunder, to neglect the great bell at Moscow, if it be good for any thing.

types in 1720, where more ingenuity was employed than had been done previously. But nevertheless there was but little effected in the bolder parts of this art; if we except some attempts made by Baskerville of Birmingham. Messrs. Fry and Son, about the year 1764, established their foundry, adopting Baskerville's method; but after some fruitless attempts to carry it into effect, found it necessary to re-cut the whole of the letters so founded on the Caslon plan. Mr. Jackson who had served his apprenticeship with Caslon, began business by the direction of Mr. Bowyer, about 1770, and cut some very extraordinary and beautiful types. He also cut a new Arabic type for Richardson's Dictionary of that language, as well as a copy of the Alexandrian Testament for Dr. Woide, which is now in the Museum. He invented a method of founding the large types by a mould and matrix which had previously been cast in sand. In 1784 there was an attempt made to establish a foundry, by an ingenious gentleman of the name of Stephenson, at which much talent was displayed in all the detail of the art; but it not answering his purpose he gave it up, and the moulds and matrixes were disposed of. About this time (1792) Mr. V. Figgins, who had been long known as possessing considerable taste in all the higher departments of this art, was encouraged by Mr. Nichols to employ it on his own account. His first production was that type from which Bowyer got up that splendid edition of Hume's England, said to have been twelve years in printing. He also, under the direction of Sir William Ousely, produced a Persian type, never before attempted in England; from which, and many other works, such as good Greek, Hebrew, &c., he has established his fame as a founder in this art much to his credit and reputation.—About 1799 Mr. Thorn began his foundry, and produced some fine specimens;—but the great change in letter founding, which has given rise to all the elegant types with which our books are now printed, took place about 1800, by the enterprise of Messrs. Caslon and Catherwood; they set about re-cutting and improving the whole business. Their first attempt embraced the Italic character, to which they gave a more elegant shape by making the fine strokes of such characters more clear and chaste than had hitherto been done. This improvement they extended to the other types by making their down strokes very thick and their up ones clear and fine. This change at first fascinated the booksellers, but it has been found since very much to hurt the sight, and for which it is now rejected: these kind of types were called technically fat-faced. This alteration in the shape of the type gave life to type-founding, inasmuch as the other principal founders saw themselves about to be left behind and superseded, unless they produced their work equally adapted to the fashion then brought into vogue for using fine types. Hence the rivalship of Fry, Figgins, and Thorn, who were soon upon equal terms with their opponents Caslon and Catherwood, in consequence of which the art has improved in a very great degree, and particularly in the larger sized letters.

The business of a letter founder or cutter, as it is now followed, consists of the following particulars, viz. he should be provided with a vice, hand-vice, hammers, and files of all sorts, similar to those made use of by watch-makers, and suitable to the several letters to be cut; in addition to which he will require a flat-gauge made of box to hold a rod of steel on the body of the mould, and fitted exactly perpendicular to the flat of a file. A sliding gauge, the use of which is to measure and set off the distances between the shoulder and the tooth, and to mark it off from the end or edge of the work. A face gauge, which is a square notch cut with a file into the edge of a thin plate of steel, iron, or brass of the thickness of a sixpence only, and which is used for proportioning the face of each sort of letter; viz. long letters, ascending letters, and short letters: there must be three gauges, one of which, for the long letters, is the length of the whole body, and supposed to be divided into forty-two equal parts; the gauge for the ascending letters, either Roman or Italic, are five-sevenths or thirty parts of forty-two, and thirty-three parts for the English face. The gauge for the short letters is three-sevenths, or eighteen parts of forty-two of the whole body, and for the Roman and Italic twenty-two parts of the English face. The Italic or other standing gauges are to measure the scope of the Italic stems, by applying the top and bottom of the gauge to the top and bottom lines of the letters, and the other side of the gauge to the stem of the letter, for when the letter complies with these three sides of the gauge that letter has its true shape. The next care of the letter cutter is to prepare himself with good steel punches, well tempered, and quite free from vents or veins, on the face of which he draws the exact shape of the letter with pen and ink, if the letter be large, or with a smooth blunted point of a needle if it be small; and then with sizeable and properly shaped and pointed gravers, with which he digs or sculptures out the steel between the strokes or marks he has previously made on the face of the punch, and which he leaves standing. Having well shaped the inside strokes of his letter, he deepens the hollows with the same tools: for if a letter be not deep in proportion to its width, it will when used at press print black and be good for nothing. This work is generally regulated by the depth of the counter part; these are worked on the outside with proper tools and files till it be fit for the matrix. But before we proceed to the sinking and justifying of the matrixes, as they are called, a mould must be provided for the purpose. Every mould is composed of an upper and under part. The upper part is in all respects made like the under part, excepting the addition of a stool behind the latter connected with a bow and spring. It has a small round wire between the body and carriage near the break, where the under part hath a small rounding or groove made in its body. This wire,

or

or rather half wire, in the upper part makes the sinking in the shank of the letter, when part of it is received into the groove in the under part; their two parts are exactly fitted, by being gauged into one another, viz. the male gauge into the female gauge, that when the upper part of the mould is properly placed on, and in the under part of the mould, both together make the entire mould, and it may be slidden backwards for use, so far that the edges of either of the bodies on the middle of either carriage comes just to the edge of the female gauge as it is in each carriage; and they may be slidden forwards so far that the bodies of either carriage may touch each other, and the sliding of these two parts of the mould backwards makes the shank of the letter thicker, because the bodies in each part stand wider asunder, and the sliding them forwards makes the shank of the letter thinner by the bodies on each part of the mould coming closer together. The parts denominated the mould consist of the carriage body, male-gauge, mouth-piece, register, female-gauge, hag and bottom-plates, and a piece of wood on which lies the bottom-plate, also the mouth, throat, pallet, nick, stool, spring, bow, &c. Having proceeded so far, the mould must be justified as it is called, and which is done by first justifying the body, which consists in casting about twenty proofs or samples of the letters, which are all set in a composing stick with their nicks towards the right hand; after which, by comparing these with the pattern letters set up in the same machine, the exact measure of the body to be cast is seen. The caster now tries if the two sides of the body are parallel, or that the body be no bigger at the head than at the foot; and this he does by taking the number of his proofs, and turning them with their heads to the feet of the other half, and if then the heads and feet be found exactly even upon each other, and neither to drive out or to get in, the two sides are deemed to be parallel. He farther tries whether the two sides of the thickness of the letters be parallel by setting the proofs in the composing stick with their nicks upwards, and then turning one half with their heads to their feet of the other half; and if the heads and feet be exactly on each other, and neither drive out nor get in, the two sides of the thickness are considered as parallel. The mould thus justified, the next business is to prepare the matrixes. A matrix is a piece of brass or copper of about one and a half inch long, and of a thickness in proportion to the size of the letter it is intended to contain. In this metal matrix is sunk the face of the letter intended to be cast, and which is done by striking in the letter punch a small way; after which the sides and face of the matrix must be justified or proved, and cleaned with files to get rid of all bunching made by the sinking of the punch. Every thing being thus prepared, it is brought to the furnace, which is built of bricks upright and with four square sides. The stove for the fuel and metal being at the top, a round hole is made for the pan to contain the metal, and which is put into a stone hollowed out to receive it. Foundrys of consequence have several of these kinds of furnaces attached to them.

The metal of which the types are to be cast is genenerally prepared in large quantities by being fused and run into bars of about 20lb. each; these are cut and delivered to the workmen in such quantities as are required for the castings he is about to perform.

There are in use among the type founders of the present day about twenty different sizes of types, all of which are cast in moulds and matrixes; besides about ten more which are usually cast from patterns in sand; however, the preference being given by the founders to moulds and matrixes, they are now beginning to cast these latter letters in that way also. To give a tolerably correct idea of the various sized types now made use of, we shall add the number and size of the lines each will make in a foot, and accompany them by their present prices at per pound. The types are known by the following designations, viz.

TABLE.

	No. of Lines.			s.	d.
The Diamond of -	204	to each foot,	per lb.	15	0
Pearl - - -	178	———	—	8	6
Nonpareil - -	143	———	—	7	6
Minion - -	128	———	—	5	6
Brevier - -	$112\frac{1}{2}$	———	—	4	6
Bourgeois - -	102	———	—	4	0
Long Primer	89	———	—	3	4
Small Pica -	83	———	—	2	10
Pica - - -	$71\frac{1}{2}$	———	—	2	10
English - -	64	———	—	2	10
Great Primer	51	———	—	2	6
Paragon - -	$44\frac{1}{2}$	———	—	2	6
Double Pica -	$41\frac{1}{2}$	———	—	2	6
Two-line Pica	$35\frac{1}{4}$	———	—	2	4
Two-line English	32	———	—	2	4
2-line Gt. Primer	$25\frac{1}{2}$	———	—	2	4
2-line Double Pica	$20\frac{3}{4}$	———	—	2	4
Cannons - -	18	———	—	2	2
Four-line Pica	$17\frac{3}{4}$	———	—	2	2
Five-line Pica	$14\frac{1}{4}$	———	—	2	2

The Hebrew, Greek, and all oriental characters are charged for at double prices. The large sized letters are those which are usually cast in sand, called "sand-letters;" they are divided and charged as follows, viz. 6, 7, 8, 9, 10, 11, 12, 14, 16, 18 lines Pica at 2s. per lb. The method adopted in casting the smaller types from Diamond to Five-line Pica is by the punch, which is formed of steel, with some letter of brass, with its outside edge boarded for the purpose of holding it more conveniently by the circular-spring, which is so fixed as to keep the matrix in its right place; and which is of a size so as to be easily held in the hand; this forms the mould of the body or shank of the type, and is adapted to cast every letter, figure and point, with the alteration of changing of what is termed the matrix. There is a very great accuracy required in the mould and

and matrix of the type founder, and this will appear very obvious, if it be considered how many thousands of little types are placed together even in a common newspaper. To make a matrix, the letter must be cut first on steel, which is brought to so soft a state as to be easily cut with a graver. Some founders prefer striking the inside openings of the letter with another punch, and which they call the counter-punch: the outside parts are then filed up with files suited to the purpose. This operation is a very delicate part of the work, and will require the greatest care and expertness, keeping in view at the same time the following particulars, viz. that the letter about to be cut should be as clear as it is possible to make it, and no uneven parts left by the graver or the file, but so finished, that however hard the impression may be, nothing but the face of the type should be allowed to print. The letters should also be of the same gauge or size, so as to range even both at the top and bottom; for without it, the beauty of the printing would be spoiled; and farther, if some of the letters should appear larger or smaller than others, it would be liable to a similar objection. The m is generally the first cut, and with the assistance of a gauge; all the other letters are cut so as to correspond to it. The letter cutter must also take care that his new letters have all the same proportions, and that the down or fat strokes be quite uniform. When the punch is ready, and it is esteemed so by being first hardened and tempered: it is struck a given depth into a piece of oblong square copper, which is previously prepared on one side by being burnished, this is the matrix; after which it is put into the hands of the justifier, to be so adjusted that all the types that are to be cast in it may range or line with the other letters of the same fount. If it happen that they be Roman letters they must so stand as to be perfectly upright, and if Italics all preserve the same inclination, standing at the same time compact and at proper and equal distances from each other. The justifier has it not in his power to alter or amend the face of the letter, it will remain as it was originally cut; his business being only to put the matrix into such a state as that it may cast fac-similes of the letters punched. Sometimes when the letter is first struck, it may turn out to be too thick, and would stand so, m m a m; in which case he files it away from the sides of the matrix, and again tries it, and continues to file it till it be brought so as to stand, mmam. Nothing is more unpleasant than to see the types in printing stand as though something was to go between them, and perhaps others crowded together so close as almost to touch. In a well executed fount every word, though it may be made up of separate types should present one whole and uniform piece. Great care, patience, and skill are necessary in this part of letter-founding. It is possible that a very indifferent cut fount may by good justification make a respectable appearance in print, whereas the best if badly justified would not be tolerable. The mould and the set of matrixes being quite ready they are consigned to the hand of the caster, who is previously provided with a platform to stand upon, and which is raised up about three feet from the floor, and also with a furnace as before described; he has a bench too on which he puts his work, and a board standing up before him to keep off the melted metal from scalding him while casting. After all is so far ready, his first business is to try the matrix of the letter he is going to cast, m, for instance, comes first in the mould; he begins by taking up the mould in his left hand, and with his right puts up the circular spring to keep the matrix close up to the face of the mould, and then with a small ladle adapted to the size of the work, he takes from out of the pan on the furnace as much metal as will fill the mould, and at the same instant that he turns the metal from out of the ladle into the mouth of it, he throws up his hand in which is held the mould with a sudden jerk or shake, thus he forces the melted metal down into the face of the matrix. The expertness with which this shake is performed, constitutes a good or bad caster; for if it be not performed so that the matrix and mould by the jerk are forced down against the metal, it is likely to turn out a bad letter. After the letter is cast, he releases the spring and takes the face of the type from the matrix, and which is done by pressing the thumb of his right hand against the top of the matrix; and then he picks out the type and goes on again with the casting.

In the casting of every type there are five distinct operations to be performed; for instance, 1st. to put up the spring; 2d. to run in the metal and make the jerk; 3d. to release the spring; 4th. to deliver the face; 5th. to open the mould and pick out the type: these are all distinctly performed at the manufacture of every letter, and so conveniently is the apparatus for doing them formed, that an expert caster can on an average make from six to seven thousand letters per day. When a caster has cast as many letters as are wanted of the same mould, he exchanges the matrix for another, and clears away the other letters from his bench or table; a *boy*, called a *breaking-off* boy, is then employed to take off the break or rim of the letter; this he does with such expedition that some boys will break off five or six thousand in an hour; when he has taken off all the breaks he returns them to the caster to be remelted and recast into other types. From the breaking-off boy the new types are put into the hands of the rubber, to have their rag or beer as it is called removed, and which is done so as to allow the letters to be afterwards placed even and regular. The rubber does this by rubbing the two flat sides of the type only, taking it up by his right hand and placing its face uppermost between his two fore fingers; he afterwards rubs it backwards and forwards, he then turns it at the edge of the thumb of his right hand and rubs its other side also on the same stone, dropping the types as fast as so rubbed into his apron, which being tied round him, and put under the stone forms a cup to receive the rubbed types. The rubbing is performed with great rapidity by an experienced rubber,

rubber, as he can do from twenty to twenty-five thousand a day.

There are some kinds of letters that never come into the hands of the rubber, and these consist of the Italic *f*, *ff*, *fi*, *fl*, *ffi*, and *ffl*, with some of the Roman also; these are f, j, ff. The letters called kerned of the Italic character are nevertheless an exception, as they will be required to be rubbed on one side only; these letters are *d*, *g*, *j*, *p*, &c. The kerned letters are afterwards put into the hand of the kerner to kern, which he performs by fixing a file into the edge of his bench by its shank, after which he lays with his right-hand the type obliquely on the file, so that the kern shall hang over it; then with his thumb on the type and his forefinger under the file he forces it up, and then drawing it down again drops it into his lap as the rubber does. When he has so kerned all the types requiring to be done he lays them all singly on a stick called the kerning stick; after which a knife is used to cut away that part of the swell of the type which would otherwise prevent its laying close to the one which is to follow it. This part of the work is tedious, and the most expert hand at it cannot do more than from five to six thousand a day. The types thus rubbed and kerned are to be taken by a boy who is called a setting-up boy. His business is to arrange them with the nicks and faces, which he does on sticks about two feet six inches in length. This is performed very rapidly, as a boy will place from twenty-five to thirty thousand a day. They are now to be consigned to the hand of the dresser or finisher, whose business is to smooth the two sides (or as it is techically termed the back and nick of the types) which the rubbing had not done, and also to make even the foot of the type where the run was broken off after casting, and to take out all the bad types that had failed in the casting, or had been spoiled in some of the subsequent finishings. It will be difficult to convey a complete idea of the mode of dressing types, but we will attempt it. The types are, as before stated, arranged on sticks. The dresser is provided with what is called a bed, which is fastened down on his bench. It consists of a square piece of mahogany or oak of about two feet four inches long, one foot wide, and four inches and a half in thickness; this is hollowed out to the depth of one inch and three quarters, and tapering in its width from seven inches at one end to six inches at the other. In this hollow are placed the blocks, in which the types are put with their feet upwards, for the purpose of planing off the roughness which had been left by the break and run.

The blocks on which the letters are dressed are made of good seasoned beechen wood, and in two parts, each of which is about one foot ten inches in length and one inch and three quarters square. One of them is provided with a tongue, and the other with a groove to receive it. The types are placed with their faces downwards on the tongue in the block, after which the two blocks are wedged together, the part of the tongue not occupied by the types entering the groove in the other block, which completely secures them to the blocks and bed. By this means five or six hundred types are firmly fixed, and ready to be planed; which is done by using a plane with a tongue of iron that moves in a groove cut in the upper square of the block, and parallel with the type in it, and so worked as just to plane out the breaks of the letters; after which the types are loosened from the blocks and taken out and laid upon a stick, and then with a knife having two edges rather concave inwards, made by grinding it so, first one side of the letter is scraped and then the other. The dresser afterwards tries them, to detect the errors, if any have been made by the justifiers or casters, and then with a glass picks out all the imperfect types. When so much is done, they are given into the hands of a telling and passing boy. He counts out for the multiplied purpose of paying the several distinct hands which have been employed on the types, such as the caster, breaking off boy, rubbers, kerners, and setting-up boy, and who are all paid by the piece at so much a thousand. An expert caster cannot get more than 30s. per week, and the other persons employed in and about the letter foundry in the same proportion.

The letter caster has also a duty to perform not yet mentioned, which consists in his seeing that the fount be cast regular, and that the letters keep their due proportions; and the necessity of due attention being paid to this must be more or less obvious to every English reader, inasmuch as the number of letters used are so very different from each other; as, for instance, in the proportion which e is to 12,000 so it is to 16,000 of b. The types may now be considered as finished, and are to be counted out by a boy in pieces making the size of an octavo page, and if not for exportation or the country, they are put into a wrapper and rolled up and put by in what is technically called a "coffin."

Besides the making of the types already described, there are also required in printing, spaces; these are used to separate the words. Quadrats are also wanted to fill up the ends of short lines, &c. Of these kind of types there are generally cast four sizes, designated by the thick, middle, thin, and hair; of the quadrats, n, m, 2 m, 3 m, and 4 m. The thick spaces are in their thickness equal to three of the body of the type, the middle four, the thin five, and the hair is made as thin as it can possibly be cast. Of the quadrats, the n is equal to one-half of its body; the m an exact square of its body, and the 2 m equal to two of its body, &c. &c. These kind of types are all cast without a matrix, and in manner following, viz. by the fixing of a piece of copper only on the face of the mould, and not removing the spring while casting them, which the caster is obliged to do in casting the other types. By this means he will be enabled to perform in a day almost as many more castings of these kinds of type-spaces as he can of the letters.

The metal of the type-founder consists of lead and regulus of antimony fused together. It is made of many different degrees of hardness by putting different quantities

of each together, and this is regulated by the size of the types about to be founded with it. For the smallest sized types the hardest metal is required, which is made of the following proportions, viz. 25 regulus to 75 of lead, and for the other sizes sometimes as low as 15 regulus to 85 of lead. The method of casting the large sized types consists in punching the letter through a piece of brass, and afterwards rivetting it on a back to form a matrix. These kind of moulds are too large to be held in the caster's hand for the purpose of founding. The weight of the metal being adequate of itself to completely fill the mould without the shake or jerk had recourse to in common casting. These kind of moulds are hung up, and the heated metal is poured into them. The largest types of all are cast in open sand similar to brass casting, already explained under that head.

The moulds and matrixes of the letter-founder are so valuable, that, if lost, nothing could restore them, it being a work in collecting them of more time than the ordinary life of a man. Hence founders keep their matrixes in strong rooms of iron or stone, into which they are placed by the superintendent of the foundry as soon as done with and every night.

The mould of the type-founder is composed of two sides framed together, and called the upper and under sides, and formed by preparing two pieces of flat steel three inches in length, three-eighths of an inch in thickness, and seven-eighths of an inch in width, and this last dimension constitutes the length of the body of the type; these together are called the carriages, on each of which is fastened down, on their right-hand side, another piece of steel, in length equal to one-half of that of the carriage, and is of the same width as the carriage, and of a similar thickness to the body of the type intended to be founded in the mould. Such pieces of steel are called the bodies of the moulds, and are fastened down to form it by a screw which is made to pass from the under part of the carriage and through its body, and also by the block, which is afterwards driven downwards through apertures made in both the body and carriage, and having above a head in length equal to one and a half of that of the body of the carriage. An opening of the same length and width is made on the left-hand side of the carriage, which is termed the block-notch. The whole is received on plates, which are regulated so that their lengths are equal to that of the carriage, and their width is two inches and three quarters. The carriage and body are so fixed as to be almost three-eighths of an inch above the bottom of the plate, and are fastened by a short screw going quite through the plate, and into the body at a place just behind the block-notch. The other opposite end of the carriage is received by the shank of the block, and passes through the plate as well as the body and carriage, which is secured by a screw fastened by a nut. Before the body is finally fixed down on the carriage, the nicks are placed in it, which consist of small pieces of steel; regulated both in their size and number by the nicks designed to be made in the types. These are all neatly let in between the body and the carriage on the upper side of the mould. In the body part of the under side there are also openings made just to receive the nicks. Above the body and carriage is screwed to each plate a piece of steel one inch in its length, and turned up a little on its inner or right side, and projecting so as to come exactly even with the front. This is termed the *face* of the mould, through which the metal descends to the type; the opening to which is sometimes increased by affixing on each side a piece of brass called its mouth-piece. On the opposite edges of the carriages and bodies are screwed the registers, which consist of pins of steel of nearly the length of the body, and standing up as high as the blocks: on the underside of which is passed a plate to fix a letter above it, which will make it come even with the face of the carriage and its body. A piece of steel called the stool is also fixed for the matrix to stand on, which is to regulate it to the mould and register. Opposite to the stool there is a hole made, through which the matrix is to pass. After the whole is so far arranged and prepared it is fixed on boards to be cast; to the lowermost of which a circular wire spring is fixed, which is so adapted as easily to turn over the stool for the purpose of keeping the matrix firmly on it, and also close up against the face of the mould. On the top of each of the boards, and just opposite the opening where the metal is to be poured in, is placed a small piece of wire three inches long, rather bent at its upper end, and called "the hag," the purpose of which is to allow the caster more easily to take the type out of the mould after it is founded.

There has been no improvement of any great importance in the manufacture of types for the last sixty years. The letter-founder's talent having been more directed to improve the face of his letters than the method of casting them. There was nevertheless a scheme set on foot about five years since by a Mr. White who had come from America, which had for its object the enabling the founder to cast a great number of letters at one time, we believe thirty or more; this was explained to most of the principal founders, and with much plausibility too; although it was by them finally rejected, but not without a trial having been previously made. About the same time a Mons. Didot proposed a plan for a similar object, assisted by Mr. Donkin an Engineer. Their machine was intended to abridge the labour by performing the whole operation of the work by the assistance of a boy only. They erected their machine, and invited the founders to see it work, to whom they offered the invention. The contrivance is generally admitted to be in the highest degree ingenious and novel, and very likely eventually to turn out of great utility. This invention has now been secured by a patent, but it is not yet got into work. Messrs. Caslon and Catherwood about three years since obtained a patent for an invention of theirs, which had for its object to lessen the number of motions required by the common

common method of casting. Their machine was set in motion by a small lever placed on the under side of the mould, the pressing of which with the thumb released the matrix, and delivered the face; after which, when the mould was again closed, and the thumb relieved, the wire was re-fixed to the matrix. This invention was calculated to save labour, and would enable a workman who could cast by the common method 6,000 letters a day to perform 7,500 by the using of this machine. There was some practical objections to it, but the chief was the alarm of the men, who, feared that the other foundrys might be induced to adopt it, in case of which their wages might be reduced. From the temper manifested by the men on the occasion it has now been laid aside. It is rather surprising, amidst the numerous improvements that are daily developing themselves, that none of the founders have produced either a script or musical type, at least one worthy of public notice: the first attempt at which was made by Mr. H. Fought in 1768, but it was never brought into general use. In 1784 one was cut under the direction of Dr. Arnold; it turned out, however, of too complex a nature, and was consequently but little used. A good type of this description might be considered a desideratum in typography, and were such an one to be executed in a manner becoming the genius of the times in which we live, it would tend very much to improve the taste as well as reduce the price of all musical compositions; a circumstance of no small importance, if it be considered how generally a taste for music is now cultivated.

Precious Metals.

Gold and silver, in as far as they are connected with founding, are, in comparison with the other metals, very little employed: excepting it be in the first instance, when they are run into bars or ingots. They are each perfectly homogeneous, from whatever mines they may have been taken; these metals are likewise malleable and divisible into the most minute proportions, and from their scarcity, and consequent high price, they become not too bulky for the common purposes of commerce: hence they have been employed from the earliest date as the medium of exchange between one nation and another, and they continue to be so employed up to the present time. The chemists say of gold that in colour it is an orange red, or a reddish yellow, and that it has no perceptible taste or smell, and bears a most brilliant lustre; it is in hardness equal only to $6\frac{1}{2}$, and of a specific gravity 19:3.* No other substance is equal to it in ductility or malleability; it may be beaten out into leaves so thin, that one grain will cover $56\frac{3}{4}$ square inches. An ounce of gold upon a silver wire is capable of being extended to more than 1,300 miles in length, and a wire wholly of gold of 0,078 of an inch in diameter is capable of supporting a weight of 150,07 pounds avoirdupoise without breaking. It melts, according to Mortimer, at 1,301 of Fahrenheit's thermometer, and in melting assumes a bright bluish green colour. It expands in the act of fusion, and consequently contracts while becoming solid more than most other metals, which renders it less proper for castings in moulds. It is, indeed, so soft in its natural, or as it is termed, virgin state, that it is found almost incapable of being so used: it is however found, by fusing it with small proportions of copper and silver, to become more hard, without losing its colour or brilliancy.

The Romans, according to Pancton, were the first who taught the art of alloying or mixing baser metals with their gold, which he stigmatizes as criminal.—Pliny says (lib. xxxiii. ch. 3.) that they mixed in the proportion of one-eighth alloy with their silver. "Livius Drusus in tribunata plebis Octavam partem æris argento miscuit." Goldsmiths usually announce the purity of the gold which they sell as follows,* viz. pure or virgin gold they suppose divided into 24 parts, called carats, and gold which is said to be that of 23 carats fine, means that it is mixed with an alloy of 1 part of some other metal and 23 of gold. Gold of 22 carats means an alloy of 22 parts gold and 2 of some other metal. The number of carats expressed always specifies the pure gold, and what that number wants of 24 indicates the quantity of alloy. Thus gold of 12 carats would be an alloy containing 12 parts gold and 12 of some other metal. With us the carat is divided into four grains; among the Germans into 12, and by the French into 32. The quality of the alloy has been always considered of importance; it is commonly of copper, and with some composed of a mixture of silver and copper. On this subject, a series of experiments were instituted in 1798, by Messrs. Cavendish and Hatchet, which may be seen in the Philosophical Transactions for 1803.

Silver approaches very nearly to gold in all its characteristic properties, with the exception of its colour, which is a fine white: like gold, it has neither taste or smell; its hardness is equal to 7. When melted, its specific gravity is 10,474, and when hammered 10,510. Its malleability is also excessive, as it may be beaten out into leaves of only $\frac{1}{160000}$ of an inch in thickness. Its ductility is equally remarkable, as it may be drawn out into a wire much finer than a human hair, so fine indeed, that a single grain of silver may be extended 400 feet in length. Its tenacity is such, that a wire of silver 0,078 inch in diameter is capable of supporting a weight equal to 187,13 lbs. avoirdupoise without breaking. According to the calculations of Mortimer, its fusing point is 1,000 of Fahrenheit's thermometer.

The business of founding or casting these metals is consigned to the artists known as the gold and silversmith. In the city of London they are formed into a company, and enjoy many particular privileges. Their

* Distilled water being reckoned its unity.

* The fullest treatise on gold hitherto published is that of Dr. Lewis's. See the Philosophical Commerce of the Arts.

business

business consists in manufacturing gold and silver into numerous vessels and utensils both for utility and ornament, which they do either in the mould, or beat it out with a hammer or other engine. All works requiring to have raised or embossed figures are cast in moulds, the subjects for which are previously designed by an artist, and modelled afterwards in wax. Messrs. Rundell and Bridge, who are the most extensively employed of any house in London as goldsmiths, keep constantly in their employ, for this purpose, several very ingenious artists, whose whole time is taken up in designing and modelling different articles to be cast in gold and silver, some of which embrace combinations the most chaste and classical, and are calculated to go very far in creating a taste and relish among our nobility for sculpture in basso-relievo wrought in the precious metals. W. Theed, Esq. A. R. A. is their principal designer.

Plates or dishes of silver and gold are beaten out from bars of either metal, as well as spoons and all the lesser description of goods commonly made of them. Vases, cups, and such like articles, are formed also from plates, as well as their ears or handles, which are beaten or hammered into pieces of the shape required, and afterwards soldered together; the shafts of vases and cups are in two pieces or halves only, and their ears into three or more, according to the composition of their shape. The mouldings also of such kind of utensils are performed by the hammer, and fastened to the shafts of such vessels for which they are intended by soldering.—The business of the goldsmith formerly required a much more divided labour than it does at present, for they were then obliged to prepare the metals by hammering them into plates, for the purposes required, from the ingot; but there are now in use mills called flatting mills, which reduce the ingot or bar to the thinness wanted, and at a very small expense.

Every goldsmith ought to be capable of designing and drawing, with a knowledge of modelling sufficient to understand its effect when it comes to be founded in metal. He also should be somewhat expert in chemistry and metallurgy, to enable him to assay the mixed metals, and to alloy the pure ones with address. He will also require a knowledge in mathematics to defend himself from fraud in his purchases of the virgin-metal, and also to divide it out accurately to his manufacturers, for them to work it into the various purposes for which it may be intended.

When gold or silver is melted it is poured into moulds previously formed to receive it, or sometimes into frames for founding it into bars; the methods practised for doing which is the same as that previously described for castings of brass in sand, both with regard to the frame, the manner of working the earth, and that of ranging the models or patterns. There is, however, a difference, inasmuch as the heated metal in the brass castings is taken out of the crucible with ladles, and poured into the aperture in the mould, from whence it runs into jets and patterns; while for gold and silver the crucible containing the fluid metal is taken off the fire with a pair of tongs made for the purpose, and the metal is poured from it into the moulds.

The Brazils furnish most of the gold now seen in commerce; there are, however, no gold mines worked there. The metal is disseminated in sand and other alluvial depositions.

Gold, silver, and copper, among the moderns, are employed as the medium of exchange, as these metals are found by long experience the fittest materials for money, being less subject to decay than most other articles of value. Whether coining be of equal antiquity with money may admit of doubt, especially as most of the ancient writers are so frequent in their mention of leathern-money, paper-money, wooden-money, &c. That such articles may have been used as money is not improbable; but it is extremely unlikely that in using such money, either could have been adapted to any portable shape to answer that purpose. In effect they were the commodities, and became current for one another by the way of exchange. Herodotus ascribes the invention of coins to the Lydians, and Pliny attributes it to Bacchus. Lycurgus ordered that iron money only should be used at Sparta. Silver is reported by Pliny not to have been coined at Rome until about the year 480 of the city, nor gold until about the year 640. The same author thus mentions its illegal debasement (lib. 33. c. 9) "Miscuit denario triumvir Antonius ferrum miscuit æri falsæ monetæ." In England the standard for gold is $\frac{11}{12}$, that is eleven parts of pure metal and one part of alloy. The standard for silver is $\frac{37}{40}$, that is, eleven ounces two dwts. of pure silver and eighteen dwts. of alloy, making together one pound. This proportion of silver is said to have been fixed by Richard I. by the assistance of certain persons from the Eastern parts of Germany, from which circumstance it was called Easterling; and hence the word sterling, which was afterwards the name given for the silver penny, and which is now applied to all lawful money in Great Britain. The coining of money was originally performed with the hammer, and afterwards with the mill, and then again with the hammer; by either of which methods the pieces of metal are stamped or struck with punches, or dies, on which are engraven the sovereign, effigies, arms, legend, &c. The puncheon consists of a highly tempered piece of steel, upon which the coin is sunk in relievo, and again upon the matrix, which is another piece of steel of about four or five inches long, formed square at the bottom, and rounded at its top. The moulding of the border and letters are added on the matrix with small and sharp steel puncheons, and when it is thus finished it is called the die. In coining by the mill the bars of gold or silver, after having been moulded, are taken out of the moulds, scraped, and brushed. They are then flatted in the mill, and reduced to the proper thickness to suit the species of money about to be coined; which, if it be gold-coin, the plates are previously to being sent to be milled, put in a furnace, heated, and then cooled in water; but if of silver the metal is passed through the mill,

mill without this additional heating and cooling. The plates, whether of gold, silver or copper, when reduced to their proper thickness are cut out into round pieces called blanks, or planchets. This cutting is performed by an instrument which is fastened to the lower extremity of an arbor, the upper end of which is formed into a screw, which being turned by an iron-handle moves the arbor, and lets a punch of well-sharpened steel fall on the plates to be cut, by means of which a piece is punched out; afterwards the pieces which are so cut out are brought to the standard weight by filing or rasping, and the corners and pieces of the plates left by the circles are returned to the melter by the denomination of sizals. The pieces are now weighed in a very accurate and well adjusted balance, and afterwards carried to the blanching room. Here it is that the gold blanks are brought to their proper colour, and the silver ones are whitened. For the former of which the operation is performed by heating them in a furnace, and when cooled, boiling them successively in two copper vessels containing water, common salt, and tartar; and after being well boiled in this menstruum they are scoured with sand and cleanly washed in pure water, and dried over a wood-fire in a sieve composed of copper wire. Formerly the planchets as soon as blanched were carried to the press to be struck, and receive their impression; but they are now always first milled. The machine for this purpose consists of two plates of steel in form of rulers, on which the edging of the coin is engraven, a half on the one, and a half on the other. One of these plates is immoveable, the other moveable and slides on a plate of copper by means of a handle and a wheel, or pinion of iron, the teeth of which catch in other teeth which are on the surface of the sliding plate. The planchet being placed horizontally between these two plates, is carried along by the motion of the moveable one, so as by the time that it has made a half turn it is found marked all round. For the coining of medals the process is nearly the same as for that of money. The principal difference consisting in this; viz. money having but a small relievo, receives its impression at a single stroke of the engine; whereas for medals their high relievo makes several strokes necessary, for which purpose the piece is taken out from between the dies, heated, and returned again; which process for medallions is sometimes repeated as many as a dozen or more times before the full impression is given them. Some medallions, in a very high relievo, are obliged to be cast in sand, and afterwards perfected by being sent to the press.

In coining with the hammer, the bars of metal on being taken out of the moulds are heated and stretched on an anvil, after which they are cut in pieces, farther stretched, and then clipped with shears to their required shape, and until they become reduced to the standard weight and to the size of the specie to be coined. The blanks, or planchets, thus formed are carried as before to the blanching-room, where they undergo the same operation as the milled money, and are then sent to the minter to be stamped with the hammer. For this operation two puncheons, or matrixes are used, the one called the pile, the other the truss, or quiver; each of which is engraven dent-ways, the pile bearing the arms, and the truss the image, legend, date, &c. The pile is about eight inches high and has a kind of talon, or heel, in its middle and ends. This kind of figure was given by reason of its being more easily sunk, and at the same time more firmly fastened to the block on which the money is struck. The minter for striking the coin lays the planchet horizontally on the pile and covers it with the truss, which he holds steadily in his left hand, giving to it several small blows, more or less, as the relievo of the die is more or less deep. About twenty years ago, Messrs. Boulton and Watt, of Birmingham, began to apply the power of steam to the operations of coining, and have since coined a large quantity of money, such as farthings, halfpence, penny and two-penny pieces of copper for the Government, which have been seen in circulation. They have also re-coined an immense number of Spanish dollars for the Bank, known in circulation as Bank Tokens, without their having been first melted, or any thing done to them except their being restamped. The machinery for this purpose is calculated to save labour prodigiously, as it is reported to be capable, by the assistance of three or four boys only, of striking or restamping 30,000 pieces of money in an hour, besides at the same time keeping an unerring account of the number of pieces stricken.

The coinage of England was originally performed wholly in the Tower of London, where there was a corporation for it under the title of the Mint. But lately there has been erected a gigantic building on the void ground north of the Tower for that purpose, in which has been placed an engine by Messrs. Boulton and Watt, and by this in future the national coins are to be stamped.

GLASS-MAKING.

Glass, in a chemical sense, denotes any substance or mixture, earthy, saline, or metallic, which is reduced by igneous fusion to the shape of a hard, brittle, uniform mass, which breaks with a conchoidal fracture passing into splinters, and with a high degree of lustre. Most glasses of this kind are also transparent. But as the term glass is commonly used in the arts and manufactures, it signifies that transparent, solid, brittle, factitious substance, produced by the vitrification of siliceous earths with various salts and metallic oxydes, which is applicable to innumerable purposes of ornament and comfort, as well as of scientific investigation and research. Such are the definitions or descriptions of this substance; but Merret, in his notes on Neri's Treatise on Glass-Making, mentions certain characters or properties of glass, by which it is distinguished from all other bodies: of these we shall enumerate the following.—It is an artificial concrete of salt and sand or stones;—it is fusible by a strong heat, and when fused is tenacious and coherent;—it does not waste nor consume in the fire;—it is ductile when red-hot, and may be fashioned into any form, but is not malleable; and is capable of being blown into a hollow; it is frangible, always diaphanous, whether hot or cold; flexible and elastic:—it may be graven, or cut with a diamond, or other hard stones and emery;—it receives any colour or dye, and admits of being polished:—it is the most pliable thing in the world, and that which best retains the fashion given it.

It would not be consistent with the plan and object of this work, to enter very deeply into the history of Glass and Glass-making, but we may observe, that so far from its being a modern invention, it was known in the days of Aristotle, who flourished three centuries and a half before the Christian era, and who gives two problems upon glass, of which the first is, why we see through it? the second, why it is not malleable? Theophrastus, who flourished about 300 years before Christ, describes glass as having been made of the sand of the river Belus: and the sphere of Archimedes is a remarkable instance of the perfection to which the art of glass-making had been brought at that early period, namely, B. C. 209. For the sake of our younger readers, we may remind them that Virgil, in his Vth Eneid, compares the clearness of the water of the Facine lake to glass; and Horace, in his third book of the Odes, mentions glass in such terms, as shew that its transparency was brought to great perfection. In the time of Strabo, who lived in the first century of the Christian era, the manufacture of glass was undoubtedly well understood, and had become a considerable article of trade. Seneca, who lived in the same century, seems not only to have been well acquainted with glass as a transparent substance, but also understood its magnifying powers, when formed into a convex shape. Pliny relates the manner of the discovery of glass. It was, he says, first made of sand found in the river Belus, a small stream of Galilee, running from the foot of Mount Carmel. The report of the discovery was, that a Phœnician merchant ship, laden with nitre or mineral alkali, being driven on the coast, and the crew going ashore for provisions, and dressing their victuals upon the sands, made use of some lumps of alkali to support their kettles. Hence a vitrification of the sand beneath the fire was produced, which afforded a hint for the manufacture.

To come to more modern times: according to the venerable Bede, artificers skilled in making glass were brought over into England in the year 674; others, however, suppose this to have happened more than fifty years later, or about the year 726. Till this time the art of making glass, or at least of applying it to the purposes of ornamenting churches, was not known in Britain. Glass windows did not begin to be used before the year 1180, and for a considerable time they were very scarce in private houses, and considered as a kind of luxury, and as marks of great magnificence. Italy had them first, next France, and from France they came into England. Venice for many years excelled all Europe in the fineness of its glasses, and in the thirteenth century the Venetians were the only people who had the secret of making crystal looking-glasses, which they performed by blowing nearly in the same manner as a considerable quantity of the common mirror-glass is now manufactured. The regular glass manufacture was begun in England 1557; the finer sort was made in Crutched Friars, London; and the very fine flint glass, little inferior to that of Venice, was first manufactured in the Savoy. The first glass plates for looking-glasses and coach-windows, were made in 1673 at Lambeth under the protection and auspices of the Duke of Buckingham, who, in 1670, introduced the manufacture of fine glass into England by means of Venetian artists with great success; so that within a century

tury and a half, the French and English have even rivalled and surpassed the Venetians, and we are no longer supplied from abroad. The French made a considerable improvement in the art of glass-making, by the invention of a method to cast very large plates, till then unknown, and scarcely even yet practised by any but themselves and the English. That court applied itself with great industry and ardour to cultivate and improve the glass manufacture. A company was established by letters patent, and it was provided by an arret not only that the working in glass should not derogate any thing from nobility, but even that none of lower degree than nobles should be allowed to work therein. In 1665, under the celebrated Colbert, a company for "blown mirror-glass" was established at Cherbourg, on the plan of the Venetian manufacture; but the art of casting glass was invented in France about the year 1688. A company was soon established for this branch of manufacture, which was first carried on at Paris and soon after removed to St. Goblin, where it probably still exists. An extensive manufactory of this kind was established in this country, near Prescot in Lancashire in the year 1773, and they have succeeded in producing plates, rivalling, if not surpassing in size, quality, and brilliancy the most celebrated continental manufactures. This company, now in London, furnishes plates from 12 inches to 12 feet in length, and full half these dimensions in breadth.

Of Mineral Combinations with regard to Vitrification.—Glass presents a great variety of qualities; but as this essentially belongs to the proportions of the substances employed, and particularly to their different degrees of purity, we shall confine ourselves to detailing the general principles upon which vitrification is founded, and the principal operations by which it is executed. Pure substances vitrify with difficulty, and the glass which proceeds from them is in general dry and very brittle. But the same substances mixed, enter more easily into fusion. Alumine and lime, although unvitrifiable separately, are easily reduced into glass when mixed together. The alkalis facilitate the fusion and vitrification of all the earthy principles. On account of this property, these salts are employed for forming the base of the composition of glass manufactured for our use. Besides the degree of fusibility which the alkalis communicate to the earthy substances, they give to the glass which proceeds from their mixture with the earths, a pliability which admits of its being wrought, blown, extended, and even hammered while it is warm and soft. The manufactories where glass is made are called glass-works. The compositions, the working, and the furnaces, vary in the different manufactories, according to the nature of the glass made in them: hence the various denominations of bottle-glass, flint-glass, plate-glass, crystal-glass, &c. But whatever may be the nature of the glass to be made, there are certain principles essentially dependent upon science which are applicable to all glass-works, and according to which all the operations are directed. These general principles have for their object every thing relating to the manufacture of the pots or crucibles, to the composition of the substances, to the construction of the furnace, to the management of the fire, and to the manner of working the glass. We shall glance at each of these subjects in succession.

Of the Manufacture of Crucibles, or Glass-Pots.—Good crucibles ensure the success of a glass-work. This truth can only be felt by those who have appreciated the loss occasioned by pots which break or melt, the loss of time, and the difficulty of replacing them. Clay forms the basis of glass-house pots. But as the qualities of clays are very variable, because they are naturally and constantly mixed in various proportions, with lime, silex, iron, and magnesia, which renders them more or less fusible, the clay must be picked before employing it. The qualities of a good clay are as follow: 1st. It must not vitrify upon an exposure of several days in the hottest place of the furnace. 2nd. It must preserve its form without sinking down, or becoming soft. 3rd. It must be wrought and moulded easily. 4th. It must undergo the action of the fire without contracting, or cracking. 5th. Good clay assumes, upon being fired, a very great hardness and compactness.

When we have ascertained all these qualities in the clay, it must be still picked, in order to separate from it every thing foreign or prejudicial. To this effect it must be carefully picked, in order to take out the pyrites and all the small coloured veins, which render it fusible: we may content ourselves with raking together the pieces tinged with ochre, and separating all the colouring principle from them. After having taken away every visible impurity, the clay must be diluted and soaked in water; it is afterwards passed through sieves, in order to separate the coarse, weighty, and insoluble bodies from it. Sand, quartz, or mica, do not sensibly injure the qualities of clay, particularly if they are in small quantity: but mixtures of calcareous earths, plaster, pyrites, and metallic oxydes, render clay improper for glass-house pots, as it is material to give to the sides of a crucible such a thickness only as to render it capable of resisting the effects of the substance it contains, and the shocks it receives in the work.

M. Loysel has suggested, that we should calculate the tenacity of the clay, by forming small sticks of it in the form of parallelipipedons, which he dries at a temperature of 25 degrees of Reaumur, and one of the extremities of which he reduces to a diameter of six lines. He fastens this extremity in a cubical cavity; and at the distance of 18 lines he suspends, from one of these sticks, the saucer of a pair of scales, in which he places weights until they produce a fracture in the stick. He observed, that good clay employed for crucibles of three feet diameter by three feet six lines thick, did not break, except with a weight of 56 ounces; and that of a furnace of fusion of eight feet diameter, by a weight of 24 ounces. But clay, employed by itself contracts too much, and it is mixed for forming the composition of pots, with the broken pieces of crucibles, ground, and

and well cleared of all vitrified matter, or with clay strongly fired. Great care must be taken not to employ sand in forming pots, because the alkali employed in making the glass would act upon the sand, dissolve it, and speedily destroy the crucibles. After having prepared the clay well, it is mixed with the cement formed of ground fragments of crucibles, and a paste is made with it which has such a consistence that a leaden bullet of four ounces weight may sink into it completely upon falling from a height taken between 66 and 83 inches. This paste must be dressed with the greatest care in a proper place, and out of the way of all dust, and the mixture of every foreign substance. When the paste is thus prepared, either the one or the other of the two following processes may be employed for making the crucible. 1st. In some glass-houses they have a wooden mould, furnished in the inside with a strong and well-stretched cloth. Rolls of paste are applied to the interior surface of this cloth, and the frame of the crucible is successively raised, by gradually diminishing its thickness from the bottom to the upper edge. 2d. In other glass-houses, the workman has a round piece of wood, a little broader than the crucible is to be, and he raises with his hand, and without a mould, his crucible upon this kind of foundation. This last method is preferable to the former, because the workman can work his paste at all places, and he leaves no cracks nor crevices in the body of the crucible, and he can join perfectly and uniformly all the parts. This process is particularly necessary in the bottle glass-houses, because this composition corrodes the crucibles more than any other. When the pots are manufactured, they are allowed to dry in the shade, at a temperature of 10 or 15 degrees of Reaumur's thermometer. We should equally dread a too strong heat, which might crack the pot; or a too sharp cold, which might freeze it; dampness and currents of air should be also carefully avoided: the apartment which serves as the drying-place should be shut, and very little frequented. When the pots begin to be dry, they are enclosed in a close place, where the heat is constantly kept up to 25 or 30 degrees of Reaumur. From this they are brought out to be put in use. For this purpose, they are exposed by degrees to a heat which produces redness, and in this state they may be placed upon their seat in the furnace. Prudence requires, that they should not be charged with any composition after they are placed upon the furnace, until they have undergone the strongest possible heat for 24 hours.

Of the Construction of Glass-House Furnaces.—The paste intended for making the bricks of a glass-house furnace is prepared by mixing crude with fired clay, or rather, with broken pieces of crucibles: white infusible quartz, or a very refractory sand, are also employed instead of fired clay. In order to pound the pieces of quartz more completely, they are made red-hot, and then thrown into water. This operation, as is well known, renders them pulverulent, without hurting their refractory quality. Bricks are sometimes used which have not been fired; these are merely dried in the air to such a degree, that a leaden bullet, falling from a height of from 25 to 45 feet, only sinks half its bulk into the brick. The furnace of a glass-house is always erected in the middle of very spacious premises, in order that the working and the surface of it may be easy. The draught of the furnace is effected by means of four currents of air, which enter the hall at separate apertures, and unite at right angles at the grate of the fire. The interior form of the furnace is almost always that of a square, or of a rectangular parallelogram, the broadest sides of which are occupied by the pots, which are supported and fixed on trevets or shelves. The interval between these shelves or trevets, forms the grate upon which the combustibles are placed. The fire is fed by apertures made in the sides: the pots are charged and emptied by means of openings immediately above them, and which exactly correspond with them, in order that the business may be more easily conducted. The furnace is surmounted or terminated by an arch, which rests upon the two longest sides, and which is full of holes, in order to establish a proper draught, and to give a passage to the flame, which also heats other arches placed before these angles, or above the vault.

Of the Substances employed in the Composition of Glass.—Silex and the alkalis form the base of glass in all countries: the other ingredients are, properly speaking, only accessary for facilitating the flux and purifying the glass, or for giving it any peculiar quality. The purest silices and alkalis form the clearest glass, and it is this composition which forms the basis of all the operations of glass-houses. But silex and alkali exist no where pure; it is only by troublesome, difficult, and expensive processes that we can bring them to this degree of purity. These substances are therefore very generally employed in the state in which nature and commerce afford them. Attention must be paid, however, among the varieties which these two substances present, to choose such as experience has shewn to give constantly the production we are desirous of obtaining. In some delicate works, such as the making of fine crystal or plate glass, the alkali of commerce is purified, in order to clear it of all foreign bodies. In general, white sand is the purest, but it is also the most refractory; the coloured sands fuse much more easily. Alicant soda holds the first place among the alkalis of commerce. It is therefore most employed in the delicate operations of the glass-works. Sicilian ashes, the salicornia and sea-wrack are employed in the manufacture of all the common clear glass. Potash and salt are also well adapted for vitrification: the latter is employed in most of the manufactories of drinking-glasses and crystal-glass, as it is called. In France, the ashes of our fires melted with sand is the most general composition of bottle-glass. When the sand is very fusible, lixiviated ashes may be employed. I have seen, says M. Chaptal, most excellent bottle-glass formed with lixiviated ashes and river sand, mixed with equal parts of quartz and rubbish of lava. The salts contained in the

the alkalis enter into fusion, and swim upon the surface of the metal (as the workmen call it), in the state of a very fluid liquid, which must be carefully taken off with a ladle or skimmer before beginning to work the glass. This precaution is only necessary when sodas are employed highly charged with marine salt. The glass-works where these kinds of soda were used, made a considerable trade of this salt, which was sold by the name of glass-house salt, when the gabelle, or salt-tax, rose to such an enormous height in France. Glass-house salt is also known by the name of gall of glass, or sandiver; and when the matter is not well melted, or when all the marine salt is not evaporated, it is found dispersed through the glass in small grains, which injure much the beauty and solidity of the article. When we wish to purify soda for delicate operations, it is dissolved in water, in order to separate by a previous operation, every thing that may be insoluble; it is afterwards evaporated, and concentrated to forty degrees of Baume's areometer, in order to precipitate the foreign salts, which crystallize; the remaining liquor is afterwards concentrated to dryness, and by this means we obtain a very pure salt of soda. We may even obtain it in crystals, by stopping the evaporation at the degree of a sirupy consistence. The proportions of the substances which form the composition of glass, vary according to the nature of the sand, the purity of the alkalis, the quality of the glass, and the degree of heat in the furnace. Experience alone must prescribe and determine the most proper composition: the more fusible the sand is, the less alkali it requires; the purer the alkali, the greater is the quantity of sand which is necessary in the composition. In order to facilitate the fusion of the compounds, and to give the glass more ductility, more weight, and less hardness; oxyde of lead is added to the composition, in variable proportions, according to the object in view. Minium, or red-lead, is always preferred for this purpose in the manufactories of crystal-glass.

The oxyde of manganese is also used, by the name of glass-maker's soap, in order to clear the glass of all colouring matter. Its effect must probably be chiefly ascribed to the facility with which it gives up its oxygen, which combines with the colouring principles, and destroys them. Too much red-lead makes the glass yellow; this defect may be corrected by applying a little oxyde of cobalt, which, in its turn, will produce a blue colour, if in excess. Too much manganese gives it a violet colour, and forms streaks, or violet-coloured ribbons, in the thick parts of the glass. This fault may be corrected, by throwing a combustible body into the melted mass. There are circumstances where a tried composition attains a proper degree of fusion with great difficulty; this may proceed from the draught of the furnace being interrupted, or when the fire is ill managed; in this case, borax, or arsenic, must be resorted to for restoring the fusion. The latter substance is held in the bottom of the pots, until it has evaporated in fumes; it spreads through the whole mass, agitates it, and hastens the flux of it. Arsenic serves in particular for destroying the green colour of glass, besides the advantage it has of facilitating the flux. The glass is coloured with the metallic oxydes; cobalt makes blue; manganese, violet; glass of antimony, yellow; precipitate of Cassius, purple; chrome, green, &c. Various colours may be obtained by the mixture of these oxydes; and we may obtain all the shades we desire.

Of the Flux of the Substances forming the Composition of Glass.—The flux of the substances embraces two principal operations; first, the fritte; second, the fusion. If we throw into the crucible, the substance which forms the composition, without having prepared it by a previous strong calcination, the crucibles would be destroyed in a short time, in consequence of the water which would be disengaged on the first impression of the fire; the flux would be almost impossible, in consequence of the greater fusibility of the alkali, which would come to the surface; the glass would be coloured, and the paste itself would experience a swelling which would drive it over the crucible. In order to obviate all these inconveniences, the substances undergo the fritte, in all the glass-works, before put into the pots to be melted. The fritte is conducted on the substances either separately or in their state of mixture and composition. The second method is preferable, for the reasons I have above given. The fritte is executed in furnaces made in the glass-house; and which very often communicate with the melting furnace, from which they receive the heat by apertures made at the base of the great arch, and at the angles. These places are then called fritte arches. The substances are fritted some time, keeping them red-hot, and by this means they often receive a commencement of a pasty fusion, which unites the parts of the composition so as to form one mass. The manufacturers of bottle glass, already mentioned, give the form of bowls to their composition, in order to roast it more completely. Others throw the composition, when well mixed, upon the bottom of the arch, taking care to strew it very thinly, in order that the calcination may act equally upon all the parts. Previous to putting the composition into the melting-pots, a new activity is given to the fire, and it is stirred three or four hours before charging them. The pots are charged at two, and even three times: a fresh quantity of composition is not added until the first quantity is melted. As soon as the pot is filled the fire is carefully kept up, for a longer or shorter time, according to the fusibility of the composition and the draught of the furnace. Ten or twelve hours is sufficient to melt the whole composition; but although it is well melted, it is not yet fit for working. It must be allowed to settle, to clear itself of the numberless bubbles which are dispersed through the paste; and this effect can only be produced by keeping the composition at a very liquid fusion for some hours. This operation is called fining. When the glass is thus fined down, or rendered fit for working with, the heat of the fire

fire is allowed gradually to diminish by adding no more coals to it. The vitreous mass then assumes a little more consistency, which facilitates the work.

Of working the Glass in Glass-houses.—The working of glass is very simple; but notwithstanding this, it requires a great deal of practice, and no one can expect to become a good artist in this branch of the business, if he has not acquired the art early in life. Every thing respecting the working of the glass may be reduced to the act of blowing or running it. In blowing the glass, an iron tube about five feet long is used; with this the workman takes out of the pot the quantity of glass necessary for his operation: the air, which he exhales from his lungs through the hollow of the tube into the mass of glass he has taken up, distends it; he afterwards gives this mass, while it is distending, the form and dimensions he wishes. Compasses, scissars, and other iron tools are employed to shape, pare, or dilate the glass. Care is taken to present it to the furnace as soon as it begins to cool; when again heated, and it begins to melt, it is withdrawn, in order to bestow additional labour upon it. The softness of glass, when it is made red-hot, forms such a contrast to its fragility when it is cold, that it would be difficult to conceive how easily it may be kneaded, soldered, and distended, if we did not see it actually done before our eyes. Much has been said of the malleability of glass; researches have been made in order to recover this important art, which it was thought the ancients possessed; and people have been unwilling to allow that there is no metal more ductile or more malleable than glass when red hot; or that this art, supposed to exist among the ancients, is practised among the moderns every day in our glass-houses. Plate-glass is formed by pouring melted glass upon a copper table, the surface of which is very flat, and by passing a level above the melted matter, in order to give the plate an uniform thickness. This operation is very similar to that by which metallic tablets are formed, by throwing melted metal upon sand. In order that the glass may be less brittle, it is necessary that it should be cooled very slowly: this last operation is called annealing. In the large manufactories of bottle-glass, the glass is annealed in furnaces made in the angles of the room where the melting furnace is: these furnaces are red-hot when the glass is deposited in them, and as soon as they are filled with the glass articles, the apertures are closed, and the heat allowed to subside of itself. In small glass-houses, the annealing furnace is generally placed upon the melting-furnace, or at one side of it, so as to be heated by the current of flame which escapes from the furnace; this is merely, properly speaking, the commencement of a very wide flue, and which insensibly diminishes in width the further it is removed from the fire; so that the glass deposited at its base gradually cools as it is drawn towards the extremity. The glass is annealed very imperfectly in this manner, because it cools too quickly.

Of the Combustibles employed in Glass-works.—Two kinds of combustibles are used in glass-works; wood and coals. The employment of the latter is very advantageous, but it colours the glass by producing a fuliginous matter which is deposited upon the melted mass, and tinges it of a yellow hue. When we wish to make a clear or crystal glass, therefore, we must take the precaution of covering the pots, to which only one aperture must be left, corresponding with the working-hole; this is called working with covered pots. When wood is employed, it must be carefully dried; the flux, in this case, is easier, and the work expedited. Elm, beech, and oak, are the three best woods for a melting-furnace. The resinous woods give out too much smoke. It requires an active and intelligent person to manage the fire of a glass-house; care must be taken neither to choke it with too much fuel or to let the heat fall off. It must be fed by renewing the fuel in small quantities at a time, and at short intervals. The weight of clear glass to that of water, is : : 23 : 10. That of argil and alkali : : 25 : 10. That of lime and alkali : : 27 : 10. The metallic oxydes add to its gravity.

Such is very much the practice in France: we shall now detail the processes adopted in our own country, and describe the materials made use of in the several manufactures. It will have been observed that glass contains invariably two essential ingredients, silex and an alkali; these are the only things necessary; these, as we have seen, were the only substances from which glass was made accidentally on the shores of the river Belus; the sand existed on the spot, and the saline substance was the substance in contact with the sand, and made use of as supports to the kettles in which the provisions were to be dressed. The fire, rendered fierce by being exposed to the open air, soon united the sand and the saline substances in fusion, and produced that glass which was the object of so fortunate and important a discovery.

Though sand and a saline substance are all that are absolutely necessary in the manufacture of glass, yet several other substances are likewise made use of for particular purposes, among which may be particularly noticed, lime, in the form of chalk, that is a combination of lime and carbonic acid, or what is chemically denominated a carbonate of lime, borax, the oxydes of lead, manganese, arsenic and nitre. Perhaps a brief account of these will be agreeable to the reader in this place, though we shall have occasion to renew the subjects in an alphabetical form in the second part of our work.

Silex may be found in almost all parts of the known world; but of different kinds, and of various degrees of purity, and such will be selected in the manufacture as is adapted to the nature and fineness of the glass required; the siliceous material generally used in this country is sea-sand, which it is well known consists of minute rounded grains of quartz, which are sufficiently small to be used without any other preparation than that of washing. Sand well adapted for the manufacture of glass is found on the coast of Norfolk near Lynn, and

and likewise on the Western shores of the Isle of Wight. Common black gun-flints afford a very pure kind of silex, which before they are used must be heated red-hot, and instantly quenched in cold water. The heat whitens the flints and the water splits them in every possible direction, after which they may be ground without difficulty in mills constructed for this kind of work. This ground flint is chiefly confined to the manufactures of the potteries, and is but seldom resorted to in glass-works. The alkali used in the manufacture of glass is either soda or potash. It is used in the state of a carbonate, though it is evident that the carbonic-acid-gas is driven off in the process, and the glass is a compound of silex and pure alkali, and not an alkaline carbonate. The finest flint-glass requires the best pearl-ashes, purified by solution and evaporation, but inferior glass is made with coarser substances, as barilla, where it is abundant; with common wood-ashes, and with kelp. These alkalis, it is true, are impure; but this does not prevent their dissolving the silex into a very good and perfect glass, for the very impurities, consisting of neutral salts, lime, and other earths, assist in vitrification. Glass made from these alkalis has always a greenish tinge, owing to the iron contained in them. Lime, in the form of chalk, is used only in small proportions, because if much is used the glass becomes opaque, and milky on cooling, though it was perfectly transparent when hot: hence the reason of what is called smoky glass among the glaziers. The proper proportions are, to 100 parts of silex and alkali, only 6 or 7 of quick-lime can be added. Lime, though mischievous, if used too liberally, has its particular uses when properly proportioned, for besides affording a cheap flux, it renders the glass easier to work and much less liable to crack by sudden and violent changes of temperature. Borax is the best flux that is known; its high price is the only objection to its more general use; this prevents it from being used in common glasses, but it is never omitted in the finer kinds of plate glass, and those other articles of manufacture that are required to be clear and free from specks and bubbles. Borax renders all vitrescent compounds into which it enters remarkably *thin-blowing*, as the phrase is, and therefore peculiarly adapted for being cast in a mould, which is the way plate-glass is manufactured. A very small quantity of borax will correct any deficient strength in the alkali. The oxydes of lead, of which litharge and minium are the only ones employed in the large way, are of great importance in glass-making. Litharge, of itself, melts into a very dense, clear, yellow, transparent glass, fusible at a low degree of heat; and when melted, it acts so powerfully on all kinds of earthen vessels as to run through the common porous crucibles in a very short time, like liquor through a filter, but vitrifying and corroding the bottom of the crucible in its passage. Litharge, therefore, is not only a most powerful flux to all earthly mixtures, but imparts to glass the valuable qualities of greater density, and greater power of refracting the rays of light; of bearing any sudden changes of temperature; of greater tenacity when red-hot, and therefore easier to be worked. Most of the finer glasses contain a considerable quantity of this oxyde, particularly the London flint-glass, or that species which is used for most of the purposes of the table, for lustres, and other ornamental works, which when cut into various forms display such beauty and brilliance, as to present a most dazzling appearance, for artificial gems and for most optical purposes. Glass, however, in which there is much lead, has the defect of being extremely soft so as to be readily scratched and injured by almost every hard body it rubs against. It is likewise so fusible, that thin tubes made of it will bend with ease in the flame of a candle, and will sink down into a shapeless mass, at a moderate red-heat. This quality is often very useful for chemical purposes, but in other cases it is a great defect. If lead is in excess, there is great danger that the glass will be corroded by the contact of acrid liquors.

The black oxyde of manganese has been long used in this manufacture: its ancient name was "glass soap," which proves that it was used for the purpose of clearing the glass from any accidental foulness of colour, which it might otherwise contract from the impurity of the alkali or other materials employed. The oxyde of manganese is a very powerful flux for earthy matters, which is seen in the result of all attempts to reduce it to a reguline state in the usual way of combining with a saline carbonaceous flux, and heating in a naked crucible. Not a particle of the oxyde is reduced in this way, but the crucible constantly runs down, in a heat sufficiently intense for the reduction of the manganese, together with all its contents into a green slag. The only way known at present of reducing this oxyde, is to enclose it without any saline or earthy addition in a crucible lined with charcoal, and apply to it a very intense heat. Manganese like lead gives a density to glass, and has like that metal a tendency to settle to the bottom of the pots where it accumulates, and being here out of the way of most of the discolouring additions, it yields a purple tinge immediately adhering to the bottom, and partly corrodes the pots, so that when they are worn out and broken up they are thickly incrusted with a purple vitrescent slag easily separable by the hammer.

The white oxyde of arsenic is another flux used in this manufacture: this is volatile in the fire in proportion as it approaches the metallic state, and hence it is of great advantage to employ nitre to oxygenate it more highly, and to render it more fixed. Arsenic is a powerful and a cheap flux, but it must be used only in great moderation, as taking a longer time to mix intimately with glass, and allowing it to be perfectly clear, than almost any other additions that can be employed. Glass in which arsenic is not most intimately combined has a milky hue, which increases by age; and when this oxyde is in excess the glass tends to deliquesce, and gradually to become soft, and at length a decomposition will take place. Drinking glasses,

glasses, and others used for purposes connected with our food, should not be made with this flux, as being one of the most dangerous poisons. As arsenic is entirely volatilized, when in contact with any carbonaceous matter, another use has been made of it, which is to disperse the carbon that may remain in the glass-pot, owing to any defect in the calcination of the alkali, or any other more latent cause. When this happens small lumps of white arsenic are thrust to the bottom of the glass-pots, and stirred in with the contents, and the fumes of the arsenic meeting with the existing carbon diffused through the glass unites with it, is speedily volatilized, and the glass is left entirely free both from the carbon and arsenic that was added.

Nitre is used, in glass-making, only in small quantities, and is an accessary ingredient for particular purposes. Nitre is readily decomposed, giving out a large quantity of oxygen, some nitrous gas, and azote, leaving behind its pure potash. It is of great service in destroying any carbonaceous matter in the ingredients of glass: it is also useful in fixing arsenic, and in keeping up the tinging power communicated by manganese. The same circumstance of keeping metallic oxydes up to their highest state of oxygenation, also renders this salt often useful, sometimes indeed essentially necessary in the preparation of certain coloured glasses.

While glass is in fusion the substances which enter into its composition may be considered as combined with each other, so as to form a homogeneous mass similar to water, holding in solution a variety of salts. If it be cooled down very gradually, the different tendency of the constituents to assume solid forms at peculiar temperatures, will cause them to separate successively in crystals, in the same manner as salts held in solution in water assume the form of crystals, when the liquid is slowly evaporated. But if the glass be rapidly cooled down to the point of congelation, the constituents have not time to separate in succession, and the glass remains the same homogeneous compound, as while in a state of fusion; just as would happen to a saline solution if suddenly exposed to a degree of cold sufficient to congeal it completely. Hence it should seem that the vitreous quality depends entirely upon the fusibility of the mixture, and the suddenness with which it is cooled down to the point of congelation. The solid substance is precisely the same as to its chemical composition, as if it were still in a state of fusion; the sudden abstraction of heat having been the means of fixing the constituents before they had time to assume a new arrangement. All fusible mixtures, as we have seen, of the earths with fixed alkalis, &c., may be made at pleasure to assume the form of glass, or the appearance which characterizes stone or porcelain, according to the rate of cooling; and glass may be deprived of its vitreous form merely by fusing it, and cooling it down with sufficient slowness to enable the constituents to separate in succession. Experiments have been made on this subject by Reaumur and Lewis, who have both pointed out the method of converting different kinds of glass into an opaque, white, hard, refractory substance like porcelain. Lewis, however, demonstrated, by a variety of experiments, that it is not every kind of glass that can be converted into porcelain. He succeeded only with those that were composed of a variety of constituents, because such glasses alone contain ingredients that become solid in succession. Green-glass, which is apt to acquire a crystallized form, succeeded the best with him, and he found that the temperature which was peculiarly adapted to the change, is that in which the glass is softened without being melted. It was the curious experiment of Sir James Hall on basalt and green-stone, that first led to an explanation upon what the vitreous state of substances depends. He found that glass, consisting of various earthy bodies, loses its vitreous state, and assumes that of a stone, if more than a minute or two elapses while it is cooling down from the complete fusion to the point at which it congeals.

There are, it is well known, different kinds of glass in common use in this country, adapted to various purposes. The finest is plate-glass, of which looking-glasses are manufactured: flint-glass, or, as it is frequently denominated, crystal, is not much behind the plate-glass in the excellence of its qualities. These are both perfectly transparent and colourless, heavy and very brilliant. They are composed of fixed alkali, pure silex, calcined flints, and litharge. The proportions, as far as can be obtained, will be given hereafter. Flint-glass contains also much oxyde of lead; though it is solid, it does not appear to be absolutely impervious to gaseous bodies, at least when heated nearly to the melting point. Dr. Lewis surrounded a piece of it with charcoal powder, and kept it some time in a heat not quite sufficient to melt it. The lead was revived in drops through the whole substance of the glass. Dr. Priestley ascertained, that glass tubes, filled with hydrogen gas, and heated, became quite black, from the revival of the lead. When alkaline hydrosulphurets are kept in glass phials, the inside is coated with a black rust, which is, in fact, the lead separated by the *sulphur* from the glass.

Crown-glass is made without lead; it is, therefore, much lighter than flint-glass. It consists chiefly of fixed alkali, fused with siliceous sand. Bottle-glass is the coarsest and cheapest kind, and in this but little fixed alkali enters into the composition. It consists of an alkaline earth, combined with alumine and silica. In this country it is composed of sand and the refuse of the soap-boiler, which is the lime employed in rendering his alkali caustic, and of the earthy matters with which that alkali was contaminated. Some of this kind of glass was analized by M. Vanquelin, and was found to be composed of

Silex	57
Lime	31
Alumine	4
Oxydes of manganese and iron	4
	96
Loss	4
	100

A small

A small portion of potash was also discerned, but it was too small to admit of being appreciated.

Of the different species of glass, the most fusible is flint-glass, and the least fusible bottle-glass. Flint-glass melts at the temperature of 19° Wedgwood; crown-glass at 30°, and bottle-glass at 47°. The properties that distinguish good glass are as follows. It is perfectly transparent, and its hardness very considerable: its specific gravity varies from 2.3, to 4, according to the materials of which it is composed. When cold it is brittle; but when at red-heat it is one of the most ductile bodies known, and may be drawn into threads nearly invisible to the naked eye. It is almost perfectly elastic, and of course is one of the most sonorous of bodies. Few chemical agents have any action upon it; but fluæic acid dissolves it with great rapidity.

Although glass is chiefly made of sand, flints, fixed alkalies and metallic oxydes, yet there are various other substances which frequently enter into the composition, and which should therefore not be wholly omitted in the description. "Polverine" or "Rochetta" is one that is procured from the Levant, and is prepared from a plant called *kali*, which is cut down in the summer, dried in the sun, and burnt in heaps either on the open ground or on iron grates; the ashes falling into a pit grow into a hard mass, and are fit for use when purified. "Kelp" which grows upon our coasts, and the ashes of the "fucus vesiculosus" furnish a similar salt: to these we may add the "barilla" of Spain.

To prepare Ashes for making Glass.—Take what quantity and what sort of wood-ashes you will, except those of oak; have a tub ready with a spigot and faucet towards the bottom, and in this tub put a layer of straw, and fling your ashes on it; then pour water upon them and let the ashes soak thoroughly until the water stands above them: let it thus continue over night, then draw out the faucet and receive the lye in another tub, put under the first for this purpose: if the lye looks troubled, pour it again on the ashes, and let it settle until it is clear and is of an amber colour. This clarified lye put by, and pour fresh water on the ashes; let this also stand over night; then draw it off, and you will have a weak lye, which, instead of water, pour upon fresh ashes; the remaining ashes are of use in the manuring of land. After you have made a sufficient quantity of lye, pour it into an iron cauldron, bricked up like a brewing or washing copper, but let it not be filled above three parts full. On the top of the brick-work place a little barrel with lye; towards the bottom of which bore a hole, and put a small faucet in, to let the lye run gently into the caldron, in a stream about the roundness of a straw; but this you must manage according to the quantity of lye, for you ought to mind how much the lye evaporates, and make the lye in the barrel run proportionally to supply that diminution. Care must be taken that the lye do not run over in the first boiling; but if you find it will, put some cold lye to it, and slacken the fire, and let all the lye boil gently to a dry salt: when this salt is cold, break it and put it into the calcar, and raise your fire by degrees until the salt is red hot, yet so as not to melt it. If you think it calcined enough, take out a piece and let it cool, then break it in two, and if it is thoroughly white, it is done enough; but if there remains a blackness in the middle it must be put in the calcar again, until it comes out completely white. If you will have it still finer, you must dissolve it again; filtrate it, boil it, and calcine it as before: the oftener this is repeated the more will the salt be cleared from the earthy particles, and it may be made as clear as crystal and as white as snow. Of this may be made the finest glass possible. According to Dr. Merret, the best ashes in England are burnt from thistles and hop-stalks, after the hops are gathered: and among trees the mulberry is reckoned to afford the best salt. The most thorny and prickly plants are observed to yield better and more salt than others; also herbs that are bitter, as hops, wormwood, &c. Tobacco stalks, when burnt, produce likewise plenty of salt: and it is observed that fern ashes yield more salt than any other ashes. Dr. Thomson, to whose admirable work on chemistry we have been indebted for part of this article, says the fullest account of glass-making is to be found in a treatise by Neri, an Italian. Dr. Merret, an Englishman, translated it into Latin, and enriched it with notes. Kunkel translated this Latin edition into German, with additions, which were the result of his own numerous experiments on glass-making. Kunkel's work was translated into French in 1752. An elaborate account of glass-making has been published in the "Arts et Metiers;" and since that a small volume on glass-making has been written in French by Loysell.

To make the Glass Frit.—Take white silver sand; wash it, and separate all the impurities from it, and let it dry, or rather calcine it. Of this take sixty pounds, and of prepared ashes thirty pounds, mix them well together, then set them in the melting furnace; the longer it is melting the clearer will the glass be made. If it stands for two days and two nights, it will be fit to work with, or to tinge with what colour you please. Before you work it, add forty pounds of lead and half a pound of manganese to it. Or, take ashes, prepared as above, sixty pounds, of prepared silver sand one hundred and sixty pounds, arsenic four pounds, white lead two pounds, clear dry nitre ten pounds, borax two pounds; mix all well together, and proceed as has been directed, and you will have a beautiful crystal.

Glass-blowing.—Glass-blowing is the art of forming vessels of glass. The term, however, is exclusively applied to those vessels which are blown by the mouth. The operation is exceedingly simple: the workman has a tube of iron, the end of which he dips into a pot of melted glass, and thus gathers a small quantity of glass on the end of it; he then applies the other end of the tube to his mouth and blows air through it, this air enters into the body of the fluid glass, and expands it out into a hollow globe, similar to the soap bladders blown from a tobacco-pipe. Various methods are used to bring

bring these hollow globes into forms of the different utensils in common domestic use. The first and greatest of the glass-blower's implements is the furnace, which consists of two large domes set one over the other; the lower one stands over a long grating (on a level with the ground,) on which the fuel is placed; beneath the grate is the ash-pit, and a large arch leading to it conveys air to the furnace. In the sides of the lower dome, as many holes or mouths are made as there are workmen to make use of the furnace, and before each mouth a pot of melted glass is placed. The pots are very large, like crucibles, and will hold from three to four hundred weight of liquid glass: they are supported upon three small piers of brick-work, resting on the floor of the furnace. The form reverberates the flame from the roof down upon the pots, and they are placed at some distance within the furnace, that the flame may get between the wall and the pots. The upper dome is built upon the other, and its floor made flat by filling up, round the roof of the lower dome, with brick-work; there is a small chimney that opens from the top of the lower dome into the middle of the floor of the upper one, which conveys the smoke away from it, and a flue from the upper dome leads it completely from the furnace. The upper dome is used for annealing the glass, and is exactly similar to a large oven; it has three mouths, and in different parts a small flight of steps leads up to each. A green-glass furnace is square; and at each angle it has an arch for annealing or cooling glasses or bottles. The metal is wrought on two opposite sides, and on the other two they have their colours, into which are made linnet holes for the fire to come from the furnace to bake the frit, and to discharge the smoke. Fires are made in the arches to anneal the work, so that the whole process is done in one furnace. These furnaces must not be of brick, but hard sandy stones. In France they build the outside of brick; and the inner part, to bear the fire, is made of a sort of fuller's earth or tobacco-pipe clay, of which they also make their melting pots. In Britain the pots are usually made of Stourbridge clay. It is observed, that the roughest work in this art is the changing the pots when they are worn out or cracked. In this case the great working hole must be uncovered; the faulty pot must be taken out with iron hooks and forks, and a new one must be speedily put in its place through the flames (for glass-furnaces are always kept burning) by the hands only. In doing this the man guards himself with a garment made of skins, in the shape of a pantaloon, that covers him all but his eyes, and is thoroughly wetted all over: his eyes are defended by proper shaped glass of a green colour.

We now come to describe the smaller implements, which are as follows: 1. A bench, or stool, with two arms at its ends, which are a little inclined to the horizon. 2. A pair of shears, or rather pliers, formed of one piece of steel: they have no sharp edges and spring open of themselves if permitted. 3. A pair of compasses to measure the work, and ascertain when it is brought to the proper size. 4. A pair of common shears for cutting soft glass. 5. A blowing-pipe, which is a wrought iron tube, three or four feet long, covered with twine at the end by which it is held. We may now explain the use of these tools in the manufacture of some vessel, as a lamp, &c. The operation is conducted by three workmen. The first takes the blowing-pipe, and after heating it to a red-heat at the mouth of the furnace, dips it into the pot of melted glass, at the same time turning it round that it may take up the glass, which has then much the consistence of turpentine; in the quantity of metal he is guided by experience, and must proportion it to the size of the vessel to be blown; he then brings it from the furnace to the stool, and rolls the lump of glass upon it to bring it to a round form, after which he blows through the pipe, resting the glass upon an iron plate behind the stool and rolling it backwards and forwards. The blowing makes the glass hollow, and he has several methods of bringing it to a proper shape to be worked; by simply blowing, it would assume a figure nearly globular; if he wants it any bigger, in the equatorial diameter, he lays the pipe on a hook driven into the side of the stool and turns it round very quickly, the centrifugal force soon enlarges it in the equator. If, on the other hand, he wishes to lengthen its polar diameter he holds the pipe perpendicular, the glass hanging downwards, its weight lengthening it, and to shorten the polar diameter he holds the pipe upright, the glass at the top; by blowing through the pipe the capacity is increased, and the thickness of the glass of the vessel diminished. We now suppose, that by a very dexterous application of the above methods the workman has brought it to a proper shape; he now carries it to the mouth of the furnace, and holds it in to get a fresh heat, (for by this time it is become too stiff to work easily), taking care to turn it round slowly, that it may not alter its figure. The vessel in this stage is delivered to the second, or principal workman, the other two being only assistants; he is seated upon the stool, and lays the blowing-pipe with the glass at its end across its arm, and with his left hand rolls the pipe along the arms, turning the glass and pipe round at the same time; in his right hand he holds the pliers, whose blades are rubbed over with a small piece of bees-wax, and as the glass turns round he presses the blade of the shears against it, following it with the shears as it rolls, at the end or side as occasion requires, until he has brought it to the proper size, which he determines by the compasses, though not materially altering its figure, the first workman kneeling on the ground, and blowing with his mouth at the end of the pipe when directed by his principal. The third workman now produces a small rod, which is dipped into the melting-pot to take up a small piece of metal to serve as cement; the end of this rod he applies to the centre of the glass just opposite the blowing-pipe, the principal workman directing it by holding its end between his pliers; the rod by the small piece of glass on its

its end immediately sticks to the glass vessel, and the third workman draws it away, both workmen turning their rods round, but in contrary directions; this operation forms a short tube on the end. The principal workman then takes the short tube between the blades of a pair of pliers exactly like the others, but which are not covered with bees-wax; the cold of these pliers instantly cracks the glass all round, and a very slight jerk struck upon the rod breaks it off. A hole is now made in the end of the glass, which is enlarged by the pliers while the glass is turned, until the neck is brought to the proper size and length to fit the brass cup as before described, and the inferior half of the lamp is brought to its shape and size in the same manner. In order to form the upper half, the third workman has in the mean time been preparing a round lump of glass on the end of one of the rods, which he applies hot to the end of the neck, it being guided by the principal workman, and it immediately holds tight; he then breaks off the other neck by the cold pliers, and thus separates it from the blowing-pipe. The glass is now heated a third time, and brought from the furnace to the principal workman, who enlarges the small orifice at the end by turning it round, and holding the pliers against it until he enlarges it to the right shape: it is now finished, and the third workman takes it to a stool strewed over with small coals; he rests the rod upon the edge of the stool, and with a file files the joint at the bottom neck, it soon breaks off and the lamp falls upon the coals, the distance being so very small as to be in no danger of breaking; a boy now puts the end of a long stick into the open mouth of the glass, and thus carries it to the annealing oven where it remains some hours; when taken out it must be cooled gradually, and is fit for sale.

Method of making Plate-Glass.—The materials of the finest plate-glass are white sand, soda, and lime, to which are added manganese and zaffre, or any other oxyde of cobalt for particular colouring purposes. The sand is of the finest and whitest kind, and is previously passed through a wire sieve of moderate closeness into water, where it is well stirred and washed till all dirt and impurity are got rid of. The sharpest grained sand is preferred, and indeed it is found that the grains of moderate size melt with the alkali sooner than either the very fine dust or the larger fragments. The alkali used is always soda, and there seems good reason to prefer this to potash, as glasses made with soda are found to be softer and to flow thinner when hot, and yet to be equally durable when cold. Besides, the neutral salts with the basis of soda, which constitute the glass-gall in this instance, such as the muriate and sulphate of soda, appear to be dissipated more readily by the fire than the corresponding salts of potash. Lime is of considerable use, and adds much to the fusibility of the other materials, supplying in this respect the use of litharge in the flint glass. Too much lime, however, impairs the colour and solidity of the glass. The colouring, or rather discolouring substances used are azure, or cobalt blue, and manganese. The latter is here in the state in which its effects is that of giving a slight red tinge, which mixes with the blue of the cobalt, and the natural yellow of the other materials; and if properly proportioned they neutralize each other so that scarcely any tint remains. Besides these ingredients there is always a great quantity of fragments of glass arising from what is spilt in the casting and the ends cut off in shaping the plates, which are made friable by quenching in water when hot, and used in this state with the fresh materials. Of the above materials the sand, soda, lime, and manganese are first mixed together with great care, and are fritted in small furnaces built for this purpose, the heat being gradually raised to a full red-white, and kept at this point with frequent stirring till the materials undergo no further change, nor give any kind of vapour. The azure and the glass fragments being already perfectly vitrified, are not added till towards the end of the process, which lasts about six hours. The glass-house for this manufacture differs in several particulars from the common houses for blowing glass, being about eighteen feet long and fifteen wide, made of good bricks. They are particularly distinguished from the common furnaces by containing two kinds of crucibles; the larger ones, called "pots," are in the form of an inverted and truncated cone, and in these the glass is melted. The others are smaller, called "cuvettes. Another essential part of this furnace is the flat table (of which there is one corresponding with each pot) on which the glass is cast. These tables are of copper-plate, about ten feet by six, supported by masonry; and contiguous to each, on the same level, are flat ovens heated from underneath, upon which the glass when cast and sufficiently cooled may be slid without difficulty from off the table, and then annealed. The tops of the flat oven and the table are on a level with the corresponding opening of the furnace, whence the cuvettes are withdrawn. When the glass is thoroughly melted and fine, the cuvette is filled in the following way: the workman takes a copper ladle about ten inches in diameter, and fixed to an iron handle seven feet long, plunges it into the glass-pot, brings it up full of melted glass and empties it into the cuvette, the ladle being supported at the bottom by a strong iron rest held by two other workmen, lest the red-hot copper should bend and give way with the weight of the glass within. The cuvette being filled is suffered to remain in the furnace for some hours, that the bubbles formed by this disturbance of the glass may have entirely disappeared, and the samples taken out from time to time become quite clear and limpid. The door of the furnace is now opened, the cuvette is slid out and pulled upon a low iron cradle, and immediately drawn on to the side of the copper table, where it is hoisted by a tackle and iron chains, and overset upon a table, on which a thick flood of melted glass flows and spreads in every direction to an equal thickness. It is then made quite smooth and uniform at the surface, by passing over it a heavy hollow roller or cylinder of

copper

copper made true and smooth by turning, after it is cast, and weighing about 500 pounds. At the same time, the empty cuvette is returned by the iron cradle to its proper place within the furnace. The number of workmen required for the whole process of casting is at least twenty, each of which has his separate employment. The plate being cast, the inspector examines whether there are any bubbles on any part of the surface, and if found, the plate is immediately cut up through them. The plate being now cool is slid by an iron instrument from the casting table to the contiguous annealing oven, previously well heated, and is carefully taken up and ranged within it. Each oven will contain six entire plates, and when full, all the openings are stopped with clay, and the plates allowed to remain there for ten days or a fortnight, to be thoroughly annealed. When fit to be taken out of the annealing oven they are sent away to receive all the subsequent operations of polishing, silvering, &c.; but first the edges are cut smooth and squared. This is done by a diamond, which is passed along the surface of the glass upon a square ruler in the manner of glaziers, and made to cut into the substance of the glass to a certain depth. The cut is opened by gently knocking with a small hammer on the under side of the glass just beneath, and the piece comes off, and the roughnesses are removed by pincers. The plate is then finished as far as the glass-house business is concerned. The glass is now to be polished, which is done with sand and water; the glass being first fastened down to a wooden frame, with plaster of Paris, the operation is performed by means of another glass, fastened in a frame, which is made to rub upon the other, wet sand being interspersed between the two. As the surfaces of the plates wear down, the sand is used finer and finer. Emery is next used of two or three degrees of fineness, which brings the glass to an even surface, but it is still perfectly opaque. To render it transparent, colcothar, which is the residue left in the retorts of the aquafortis makers, is applied. The polishing instrument is a block of wood, covered with several folds of cloth and carded wool, so as to make a firm elastic cushion. This block is worked by the hand; but to increase the pressure of the polisher, the handle is lengthened by a wooden spring, bent to a bow three or four feet long, which, at the other extremity, rests against a fixed point to a beam placed above. The plate is now fastened to a table with plaster, covered with colcothar, and the polisher begins his operation by working it backwards and forwards over the surface of the plate till one side is done; then the other is to be polished in the same manner.

Crown-glass is the name given to the best window glass, the composition of which varies very considerably: but a good glass of this kind may be made with 200 parts of soda, 300 of fine sand, 33 of lime, and from 250 to 300 of the ground fragments of glass that has already been worked. A small quantity of arsenic is sometimes added to facilitate the fusion. Zafre, or the oxyde of cobalt, with ground flint is often used to correct the dingy yellow which the inferior kind of crown-glass naturally acquires. The manufacture of the common window glass, though made by blowing, is carried on very differently from that of the common flint glass articles, as the object is to produce a large flat and very thin plate, which is afterwards to be cut by the glazier's diamond into the required shapes and sizes. It is difficult to convey to the reader a proper and precise idea of the process by mere description, but it may be mentioned, that the workman takes a large mass of glass on the hollow iron rod, and by rolling it on an iron plate, and swinging it backwards and forwards, causes it to lengthen by its own weight into a cylinder, which is then rendered hollow by blowing with a force of breath till it is brought out to the requisite thickness. The hollow cylinder is then opened by holding it to the fire, which, by expanding the air confined within it (the hole of the iron rod being stopped) bursts it at its weakest part; and when still soft it is ripped up through its whole length by iron shears, opened out into a flat surface, and then it is finished by annealing as usual.

Common green bottle glass is another kind, which is made almost entirely of sand, lime, and sometimes clay, alkaline ashes of any kind, according as cheapness or convenience direct, and more especially of kelp in this country; of barilla varec and the other varieties of soda, in France; and of wood ashes in many parts of Germany, and in North America. The following composition has been given as a good and cheap material for bottle-glass, 100 parts of common sand, 30 of varec (a coarse kind of kelp made on the western coasts of France) 160 of the lixiviated earth of ashes, 30 of fresh wood ash, 80 of brick clay, and about 100 of broken glass. Bottle-glass is a very hard, well vitrified glass, not very heavy relatively to its bulk, and being fused at a very high degree of heat, and from other circumstances, it resists the corrosive action of all liquids much better than flint-glass. Besides being used for wine and beer bottles, it is much employed for very large retorts, subliming vessels, and other processes of chemistry, for which it is admirably adapted, being able to bear as much as a pretty full red-heat, without melting or sinking down into a shapeless lump.

Compositions for White and Crystal-Glass.—To make crystal-glass, take of the whitest terso, pounded small, and sifted as fine as flour, two hundred pounds; of the salt of polverine one hundred and thirty pounds; mix them together, and put them into the furnace called the calcar, first heating it. For an hour keep a moderate fire, and keep stirring the materials with a proper rake, that they may incorporate and calcine together; increasing the fire for five hours; after which the matter is taken out, being sufficiently calcined, and is called frit. After this, remove it immediately from the calcar to a dry place, and cover it up from dust, for three or four months. Now, to make the crystal glass, take of the above crystal frit, called also bollito, and set it in the melting pots in the furnace, adding to it a due quantity of manganese; when the two are fused, cast the flour

flour into fair water, to clear it of the salt called sandiver, which would otherwise make the crystal obscure and cloudy. This washing must be repeated again and again, till the crystal be fully purged; or this scum may be taken off by proper ladles. Now set it to boil for four, five, or six days; which being finished, see whether it have manganese enough, and if it be yet greenish, add more manganese at discretion, by little and little at a time, taking care not to over dose it, because it will incline it to a blackish hue. Let it clarify, and become of a shining hue; which done, it is fit to be used, and blown into vessels of any kind. Or, 120 parts of fine sand, 40 of purified pearl-ash, 35 of litharge, 13 of nitre, and a small quantity of black oxyde of manganese, make a good glass.

Compositions for Flint-Glass.—Flint-glass, as it is usually called by us, is of the same general kind with that, which, in other places, is called crystal-glass. It has this name from its having been originally made with calcined flints, before the use of white sand was understood; and it has retained this name, though there are now no flints used in its composition. This glass differs from the crystal-glass in having lead in its composition, to flux it, and white sand for its body, whereas the fluxes used in the other are salts, or arsenic, and the body consists of tarso, white river pebbles, and such kind of stones. To the lead and white sand a due proportion of nitre is added, and a small quantity of magnesia. The most perfect kind of flint-glass is made by fusing, in a very strong fire, one hundred and twenty pounds of white sand, fifty pounds of red-lead, forty pounds of the purest pearl-ash, twenty pounds of nitre, and five ounces of magnesia. Another composition of flint-glass is said to be the following: one hundred and twenty pounds of white sand, fifty-four pounds of the purest pearl-ash, thirty-six pounds of red-lead, twelve pounds of nitre, and six ounces of magnesia. To either of the above compositions a pound or two of arsenic may be added, to increase the flux of the composition. A still cheaper flint-glass may be made with one hundred and twenty pounds of white sand, thirty-five pounds of the best pearl-ash, forty pounds of red-lead, thirteen pounds of nitre, six pounds of arsenic, and four ounces of magnesia; or, instead of the arsenic, may be substituted fifteen pounds of common salt; but this will make it more brittle than the other. But the cheapest of all the compositions hitherto employed, consists of one hundred and twenty pounds of white sand, thirty pounds of red-lead, twenty pounds of the best pearl-ash, ten pounds of nitre, fifteen pounds of common salt, and six pounds of arsenic. Or, 100 parts of sand, 80 to 85 of red-lead, 35 to 40 of pearl-ash, two or three of nitre, and one ounce of manganese. The oxyde of lead may be reduced in this glass.

Of silvering Glass.—Glass when smoothed and polished does not acquire the property of reflecting objects till it has been silvered, as it is called, an operation effected by means of an amalgam of tin and quicksilver. The tin-leaf employed must be of the size of the glass, because, when pieces of that metal are united by means of mercury, they exhibit the appearance of lines. Tin is one of those metallic substances which become soonest oxidated by the means of mercury. If there remains a portion of that oxyde or calx, of a blackish gray colour, on the leaf of tin, it produces a spot or stain in the mirror, and that part cannot reflect objects presented to it: great care, therefore, is taken in silvering glass to remove the calx of tin from the surface of the amalgam. The process is as follows:—The leaf of tin is laid on a very smooth stone table, and mercury being poured over the metal, it is extended over the surface of it by means of a rubber made of bits of cloth. At the same moment the surface of the leaf of tin becomes covered with blackish oxyde, which is removed with the rubber. More mercury is then poured over the tin, where it remains at a level to the thickness of more than a line, without running off. The glass is applied in a horizontal direction to the table at one of its extremities, and being pushed forwards it drives before it the oxyde of tin which is at the surface of the amalgam. A number of leaden weights, covered with cloth, are then placed on the glass which floats on the amalgam, in order to press it down. Without this precaution the glass would exhibit the interstices of the crystals resulting from the amalgam. These crystals have the form of large square laminæ irregularly disposed.

To obtain leaves of tin, which are sometimes six or seven feet in length, with a proportionate breadth, they are not rolled but hammered after the manner of gold-beaters. The prepared tin is first cast between two plates of polished iron, or between two smooth stones not of a porous nature, such as thunder-stone. Twelve of these plates are placed over each other; and they are then beat on a stone mass with heavy hammers, one side of which is plain and the other rounded. The plates joined together are first beaten with the latter: when they become extended the number of the plates is doubled, so that they amount sometimes to eighty or more. They are then smoothed with the flat side of the hammer, and are beat till they acquire the length of six or seven feet, and the breadth of four or five. The small block of tin from which they are formed is at first ten inches long, six in breadth, and a line and a quarter in thickness. When the leaves are of less extent, and thin, from eighty to a hundred of them are smoothed together.

Tin, extracted from the amalgam which has been employed for silvering glass, exhibits a remarkable peculiarity. When fused in an iron pan, its whole surface becomes covered with a multitude of tetraëdral prismatic crystals, two or three lines in length and a quarter of a line in thickness. The interior of these pieces of tin, when cut with a chisel, have a grayer tint than pure tin, which is as white as silver. The latter crystallizes also by cooling; but it requires care. When it begins to be fixed, decant the part which is still in fusion, and there will remain at the bottom of the crucible

cible beautiful crystals of a dull white colour, which appeared to me to be cubes or parallelopipedons.

Painting on Glass.—The primitive manner of painting on glass was very simple, and, of consequence, very easy; it consisted in the mere arrangement of pieces of glass of different colours, in some sort of symmetry; and constituted a kind of what we call Mosaic work. Afterwards, when they came to attempt more regular designs, and even to represent figures raised with all their shades, their whole address went no farther than to the drawing the contours of the figures in black, with water colours, and hatching the draperies after the same manner, on glasses of the colour of the object intended to be painted. For the carnations they chose glass of a bright red; upon which they designed the principal lineaments of the face, &c. with black. At last, the taste for this sort of painting being considerably improved, and the art being found applicable to the adorning of the churches, basilicas, &c., they found means of incorporating the colours with the glass itself, by exposing them to a proper degree of fire, after the colours had been laid on.

Those beautiful works, among the painters in glass, which were made in the glass-house, were of two kinds: in some, the colour was diffused through the whole body of glass; in others, which were the more common, the colour was only on one side, scarcely penetrating within the substance above one-third of a line; though this was, more or less, according to the nature of the colour, the yellow being always found to enter the deepest. These last, though not so strong and beautiful as the former, were of more advantage to the workmen; because, on the same glass, though already coloured, they could shew other kinds of colours, where there was occasion to embroider draperies, enrich them with foliages, or represent other ornaments of gold, silver, &c. In order to this, they made use of emery; grinding, or wearing down the surface of the glass, till such time as they were got through the colour to the clear glass: this done, they applied the proper colours on the other side of the glass. By this means the new colours were prevented from running and mixing among the former, when the glasses came to be exposed to the fire, as will hereafter be shewn.

When the intended ornaments were to appear white, or silvered, they contented themselves to bare the gloss of its colour with emery, without applying any new colour at all; and it was in this manner that they wrought the lights and heightenings on all kinds of colours. The painting with vitreous colours on glass depends entirely on the same principles as painting in enamel, and the manner of executing it is likewise the same, except that in this the transparency of the colours being indispensably requisite, no substances can be used to form them but such as vitrify perfectly: and, therefore, the great object is to find a set of colours which are composed of such substances, as, by the admixture of other bodies, may promote their vitrification and fusion; are capable of being converted into glass; and melting, in that state, with less heat than is sufficient to melt such other kinds of glass as may be chosen for the ground or body to be painted, to temper these colours, so as to make them proper to be worked with a pencil, and to burn or reduce them by heat, to a due state of fusion, without injuring or melting the glass which constitutes the body painted. The first thing to be done, in order to paint on glass, in the modern way, is to design, and even colour, the whole subject on paper. Then they make choice of pieces of glass proper to receive the several parts, and proceed to divide or distribute the design itself, or the paper it is drawn on, into pieces suitable to those of glass; having always a view that the glasses may join in the contours of the figures, and the folds of the draperies; that the carnations and other finer parts may not be damaged by the lead wherewith the pieces are to be joined together. The distribution being made, they mark all the glasses, as well as papers, with letters or numbers, that they may be known again; which done, applying each part of the design on the glass intended for it, they copy or transfer the design upon this glass, with the black colour, diluted in gum water, by tracing and following all the *lines* and strokes, as they appear through the glass, with the point of a pencil.

When these first strokes are well dried, which happens in about two days, the work being only in black and white, they give it a slight wash over, with urine, gum arabic, and a little black; and this several times repeated, according as the shades are desired to be heightened; with this precaution, never to apply a new wash, till the former is sufficiently dried. This done, the lights and risings are given, by rubbing off the colour in the respective places, with a wooden point or the handle of the pencil.

As to the other colours above-mentioned, they are used with gum water, much as in painting in miniature, taking care to apply them lightly, for fear of effacing the outlines of the design; or even, for the greater security, to apply them on the other side, especially yellow, which is very pernicious to other colours by blending therewith.

And here too, as in pieces of black and white, particular regard must be always had not to lay colour on colour, or lay on a new lay till such time as the former are well dried. It may be added, that the yellow is the only colour that penetrates through the glass, and incorporates therewith by the fire; the rest, and particularly the blue, which is very difficult to use, remaining on the surface, or at least entering very little. When the painting of all the pieces is finished, they are carried to the furnace or oven, to anneal or bake the colours. The furnace here used is small, built of brick, from eighteen to thirty inches square. At six inches from the bottom is an aperture to put in the fuel and maintain the fire. Over this aperture is a grate, made of three square bars of iron, which traverse the furnace and divide it into two parts. Two inches above this partition is another little aperture, through which

which they take out pieces to examine how the operation goes forward. On the grate is placed a square earthen pan, six or seven inches deep, and five or six inches less every way than the perimeter of the furnace. On one side hereof is a little aperture, through which to make the trials, placed directly opposite to that of the furnaces destined for the same end. In this pan are the pieces of glass to be placed in the following manner; first, the bottom of the pan is covered with three strata or layers of quicklime pulverized; those strata being separated by two others of old broken glass; the design whereof is to secure the painted glass from the too intense heat of the fire. This done, the glasses are laid horizontally on the last, or uppermost layer of lime. The first row of glass they cover over with a layer of the same powder an inch deep; over this they lay another range of glasses; and thus alternately till the pan is quite full, taking care that the whole heap always ends with a layer of the lime-powder.

The pan thus prepared, they cover up the furnace with tiles on a square table of earthenware, closely luted all round, only having five little apertures, one at each corner and another in the middle to serve as chimneys.

Things thus disposed, there remains nothing but to give the fire to the work. The fire for the two first hours must be very moderate, and must be increased in proportion as the coction advances for the space of ten or twelve hours, in which time it is usually completed. At last the fire, which at first was only of charcoal is to be of dry wood; so that the flame covers the whole pan, and even issues out at the chimneys. During the last hours they make assays from time to time by taking out pieces laid for that purpose, through the little aperture of the furnace and pan, to see whether the yellow be perfect, and the other colours in good order. When the annealing is thought sufficient, they proceed with great haste to extinguish the fire, which otherwise would soon burn the colours and break the glasses.

We have been favoured with some practical information on this subject by Mr. Collins, glass-manufacturer of the Strand, near Temple Bar, and to him we are indebted for some valuable receipts, which we shall present to our readers. This ingenious gentleman has always specimens of his art by him, and he is exceedingly ready to give every information on the subject to inquiring and scientific persons. He is now engaged upon a grand window for the cathedral at Exeter, and another for his Grace the Duke of Norfolk, which will probably at least rival any of our modern manufactures in this way.

"Enamel colours and painting on glass," says Mr. Collins, "differ totally from all others, it being requisite on glass that the colours used should appear transparent, and bear, (without blistering in the kiln) to be laid on very thick. In every other style of enamel painting, the fluxes must be so compounded as to bring the beauty of the colour on the surface, and they do not require to be any thing like the substance compared to those used on glass.

"Crown window glass is the best for the purpose of enamelling upon, its principal composition or *base* being silex, which is not only the best substance for receiving colours, but also by far the best as the base for the fluxes.

"The best fluxes are obtained from finely calcined flints, lead and salts forming the fusing matter; these latter must be carefully used in various proportions, as the colours or oxydes require.

"Receipts for the Colours.—From gold *only* is prepared any pink or rose colours, although it has often been asserted that the French have prepared it from *iron*, which may *sometimes* answer for an orange-red, but will never produce a pink; and is very far (even as a red) from being so fixed a colour as those made from gold, although it has been stated to be more so. In fact, a colour being well fixed (on the contrary) depends as much upon the properties of the flux being rightly prepared to receive it as on the oxyde or colouring matter itself, which experiment only can firmly elucidate.

"All metals should be as far removed from their metallic state as possible, and when in that state from which it would be the most difficult to restore it, it is best calculated for the purpose, therefore gold precipitated by *tin* is better than that by an alkali, being a much more perfect oxyde. Besides that, tin is the firmest and best base for receiving and holding the colour struck from *gold*.

"In combining the fluxes so that they shall bear the greatest possible affinity for the oxydes intended, rests the principal art of colour-making.

"In the solutions of gold and tin, it is best to use more of the nitric and as little of the muriatic acid as possible, and the larger the proportion of metal that can be dissolved in a certain portion of acids the better.

"In the solution of gold the beauty of the colour rests principally in the precipitate; to obtain the *best*, use the water *as hot as possible*; into about a pint of which drop a little *gold* (about 15 or 20 drops), then the *tin most carefully* by a drop at a time until it becomes as nearly as possible the colour of port-wine at the edge of the bason; it will then instantly precipitate itself. Wash it *several times* with very hot water; it must now be mixed with its flux before it is suffered to dry.

"Rose colour should always be made from an oxyde that inclines to the pink (as it occasionally differs); the flux should contain scarcely any lead, a small portion of silver is then added and the whole finely ground before dry.

"I have entered at greater length into the pink and rose colours produced from gold than on any others, they being by far the most difficult to produce, and should never be made but on a bright and clear sunshiny

shiny day, which I am persuaded has great influence on the preparation, as you never can produce this colour *good* with a damp atmosphere or a cloudy sky.

"Blue is made from cobalt; the best is that prepared by fire, as in Staffordshire, being more condensed than that which is prepared by the acids. It is then fused with borax ground fine and washed several times; when dry, mixed with the flux and melted together.

"Purple is made from an oxyde that inclines to the blue, and the flux may contain a much larger portion of lead, &c. as the rose colour, only omitting the silver.

"Yellows are made from varied proportions of the oxydes of antimony and lead. Tin is best omitted and silex used in its place; the whole to be well melted.

"Orange. Prepared as the yellow, only introducing a small quantity of the purple oxyde of gold, and melted as yellow.

"Brown is made from manganese and antimony ground with the flux, and well melted together.

"Black is best when made from good iron scales and oxyde of cobalt, with a little of the darkest possible purple oxydes of gold, mixed with the flux and melted together.

"Green is made from copper oxydated by fire, united with the flux, and well melted. It is then mixed with yellow to produce a grass green, and with white enamel (made by arsenic) to produce a blue-green.

"White, which is seldom used on glass, is made from arsenic mixed with the flux, and when in a state of fusion kept well covered. Tin is also considered, for some purposes, the only thing from which a good fixed white can be made, but all that I have yet seen made in this country is very bad. The Venetian white enamel can only be depended on, which latter more particularly applies to enamelling on copper.*

"Ruby. That produced by the ancients is what has made the greatest noise, the art of making which being considered lost, and for this reason principally admired. But this is an error, as that beautiful colour is now made in as great perfection as ever, and equally well understood. Ruby may be made either from gold or copper. When made from the latter the colour is liable to change by various degrees of heat, any thing above a red-heat *totally dissipating it*. That made from gold is perfectly fixed, though not quite so deep a tint; with this latter, antimony, iron, and silver are used. With the copper *red tartar*.

"Paintings on glass require infinitely more care in burning than enamel, both on account of the superior size and brittleness of the substance; it therefore requires many hours annealing.

"In the preparing of glass and enamel colours there is great difference; but the oxydes or colouring matters are alike in all, excepting the *yellow*, which *on glass* is produced from silver, on enamel from antimony.

"A fine red is produced on glass by the union of silver and antimony."

* The hard white enamel is but very little understood in this country. By some its base (as I before observed) is stated to be the oxyde of tin, but it is very doubtful. This is that substance used as the first ground or coating of the copper-plates for enamel painting, over which a somewhat more transparent and softer enamel (termed flux) is laid, which melting sooner than the first is better adapted for receiving the colours. In this style of painting so little can be done before it is necessary to fire the picture, that it frequently requires a dozen fires to complete a painting.

GLAZING.

Glazing is by no means unimportant; it is one among the numerous dispensations of Providence to promote the comfort and convenience of his people, in climates subject, by their position, more or less to the vicissitudes of an irregular atmosphere. The ancient nations were more favoured in these respects than the moderns: hence they did not so much require the protection to be derived from filling the apertures of their dwellings with glass, as is the case with us. And it is perhaps from this circumstance, that we find so very few notions among them of such an application. The windows discovered at Herculaneum and Pompeia were filled with squares of Amber, although glass was not unknown at the time; but it might have been considered of too much importance to be appropriated to such a purpose. That the Greeks had windows in their buildings, is ascertained from the ruins of their buildings still extant. The vestibule of the Temple of Minerva Polias, leading to that of the Pandrosium at Athens, has windows, or at least apertures for their reception; and from the nature of their construction, the marble jaum being adapted to receive in them a frame, it is probable these apertures were enclosed with some substance of a diaphanous nature; as there can be no doubt but

but that they were left for the purpose of admitting light as well as perhaps air. Neither is it imagined that glass windows were very common even at Rome, although most of their celebrated authors frequently make mention of glass, but it was so rare as to be attainable only by the superior people. If it had been common, or at least in the way in which we are in the habit of considering it, Nero might have gotten his drinking glasses somewhat cheaper than he is reported to have done. Another circumstance also shews that glass was by no means brought to perfection, for instead of the Roman ladies using polished plates of it at their toilet, silver highly wrought and polished was adopted. It may be said, "that although glass was not employed for mirrors it might have been for windows." To which it may be answered, "if it had been common for the latter, it could not have long remained uncommon for the former, as the silvering we employ to make it answer that purpose could have been supplied by numerous other devices."

The first notice we have of the application of glass to the purpose of glazing windows occurs in Bede's History de Locis Sanctis, c. 6, who, speaking of the church on Mount Olivet near Jerusalem, says, "in the West front of it were eight windows, which on some occasions used to be illuminated with lamps, which shone so bright through the glass that the mount seemed in a blaze." And the same author affirms, that the Abbot Benedict was the first who introduced the art of manufacturing of glass into this kingdom by bringing over artists from the Continent for that purpose. This happened about 669, at which time architecture had made considerable progress, and many religious houses were then building and had been already erected. And if it be considered to what perfection this business of glass had been brought even in a century or two after, particularly in the work of staining and painting it, &c. it will not be too much to infer that its improvement advanced with the architecture of the time; to which it was so well adapted both to give it splendour as well as improve and add a variety by its contrast.

Glazing, as it is now practised, embraces the cutting of all the varieties of glass manufactured for windows, together with fixing it in sashes by means of tacks and a stopping of putty; also the forming of casements and securing the glass by bands of lead fastened to outside frames of iron. The glazier is intrusted likewise with the windows for public buildings as well as private, composed of an infinite variety of coloured and painted glass, embracing all the diversified tints in nature, so combined by opposing them in contrary shades and figures as to produce a pleasing whole, or coup d'œil. These departments constitute the pre-eminent employ of the glazier of the present time, and is that in which he values himself most upon in performing. We have now in London several tradesmen who have pursued this part of their business with a laudable zeal, and have produced specimens of colouring as well as painting on glass much superior in point of drawing and arrangement to any that was done during the period of our ancestors. We have already referred to Mr. Collins in the Strand, and we may add Mr. Backler of Newman-street, and Mr. Miller of Swallow-street. This latter artist has been employed in the restoration of the windows to Henry the Seventh's Chapel at Westminster, in which he has shewn an antiquarian knowledge highly creditable to his talents. He has also been engaged in the restoring of several windows in the cathedrals in the provinces, and has executed some superb windows for a villa at Sunbury, in Middlesex, each window having figures in groups after the paintings of Domenichino. They are painted in all the brilliancy of colours for which the original pictures were distinguished. The mode of charging for this kind of business is regulated by the design proposed to be executed. Plain colours in glass are not much more expensive than good common glass, and may be introduced to produce a very pleasing effect of itself, observing to vary the tints and shapes of the glass. Plain coloured glass is charged by the pound, while all other glass is charged by the foot superficial, and the former varies only as the difficulty and expense of the colouring. All the common tints, for instance, orange, greens, and reds, &c. are on an average charged from six to seven shillings a pound, and blues, &c. somewhat more. The manufacture of the real ruby, for which the ancient windows in our churches are so much distinguished is now lost; and no modern artist has yet been enabled successfully to imitate it; of course all that is at present made use of is of the antient glass of that colour, and consequently becomes very dear, and difficult from its scarcity to be obtained at any price.

The most ancient species of glazing was in head-work, as our many cathedrals and religious houses, still extant, demonstrate; and fixing glass in leaden frames is still continued for the same description of buildings. The business of a glazier, if considered in its most simple operations, consists in fitting all the various kinds of glass manufactured and sold, into sashes previously prepared to receive them. The sashes as they are now made have a groove or rebate formed on the back of their cross and vertical bars adapted to admit the glass; into these rebates the glazier minutely fits the squares, which he beds in a composition called putty.

The putty consists of pounded whiting beaten up with linseed oil, and so kneeded and worked together as to make a tough end tenacious cement, and is of great durability; this the glazier colours to suit the sashes he may have in hand. If they are common deal sashes, the putty is left and used as first manufactured; but if they are mahogany, it is coloured with ochre till it approaches more nearly that of the sashes.

In glazing windows the colour of the glass is that on which the greatest beauty is given to the work; and to effect this successfully many different manufactories have been established. The most usual kind of window-glass now found at the glazier's is called crown-glass; it

it is picked and divided at the manufactory into the several different kinds which are known as first, seconds, and thirds, and which particularly denote the qualities of the several kinds of glass, the first being known as best crown, the next in quality second crown, and the last thirds, or third crown, the price of each varying according to the quality. The glass is in pieces called tables of about three feet in diameter each, and when selected and picked as above they are packed in crates, twelve of such tables being put in each crate of best glass, fifteen in the seconds, and eighteen in the thirds. The crates consist of an open framing of unhewn wood, and the glass is packed in them in straw for security. The glaziers purchase such glass by the crate, although the duty on it is collected by the pound. The price of a crate of glass varies as its quality, the best crown being now (since the late additional duty) worth per crate about four guineas, the seconds three, and the thirds two guineas. There are several manufactories for what is called crown-glass, but the most esteemed in the market is that which is made at Newcastle and in its neighbourhood.

Green glass is another of these species, and which is greatly in demand for all the purposes in which colour is not so particularly sought for. This sort of glass is used in the glazing of the windows of cottages, also for green and hot-houses, to which it is found to answer every purpose. It is not more than one-half the cost of the crown-glass. The green-glass appears to have been the most ancient kind made use of, as most of the vestiges remaining in the old windows approach very nearly in their quality to what is now sold under that designation. The glaziers also prepare the crown-glass so as to produce an opaque effect: it is adapted to prevent the inconvenience of being overlooked. It is technically called ground-glass, which is not improper, inasmuch as it is rendered opaque by rubbing away the polish from off its surface, to do which the glazier takes care to have the sheets or panes of glass brought to their proper size, then they are laid down smoothly as well as firm, either on sand, or any other substance which is adapted to admit of its lying securely. He then rubs it with sand and water or emery till the polish be completely removed; it is then washed, dried, and stopped into the window for which it was prepared. There was a species of glass made at Venice originally, which was manufactured wholly for this purpose, and is now to be seen in many counting-houses and old buildings. Its general appearance presented an uneven surface, appearing as though indented all over with wires, leaving the intervening shapes in the form of lozenges. This glass was very thick and strong, and is of the description known as plate-glass. None of it has been imported into England for many years past; in consequence of which grinding the crown-glass, as above described, has been made use of to answer the same purpose. However, at this time it is manufactured and sold in tables at the depôt for plate glass lately established in East-Smithfield, where it is known and sold under the denomination of Venice plate-glass.

The crown-glass not admitting of being cut to very large sized squares, and as the fashion of making folding sashes has become general, recourse has been had to obtain tables of sizes adequate to admit of pieces being taken out of them adapted to glaze such windows. This was first attempted at a glass-house at Ratcliff, near London; it failed however, from there not being a demand capable of supporting such a manufactory. However, at this time the Newcastle people are succeeding in producing their tables in size commensurate to answer almost every purpose.

The most beautiful glass made use of is that sold by the British Plate-Glass Company in Albion Place, which is manufactured by them at Ravenscroft, in Lancashire. This glass is nearly colourless, and of a sufficient thickness to admit of its being polished to the greatest delicacy. From this depôt looking-glasses may be obtained of surprising dimensions in point of size; and from hence it is that most of the plate-glass, so much the fashion in our windows at this time, is obtained. This company sell their glass in proportion to its size, the value increasing as it increases. At their warehouse are to be seen thousands of different sized plates, every one of which labelled of its size in inches only, as it is by inches that such glass is bought and sold.

The glaziers, in glazing windows of plate-glass, strike it out to the size required by a fine diamond, after which they break off the pieces by pincers; such glass varies in its thickness from one-eighth to as much as a quarter of an inch. Purchasers of glass of this Company may almost always get suited in the sizes they may want at the depôt in Albion Place, but if the pieces are larger than the size required, the loss occasioned by reducing it falls on the buyer, as he must pay for the whole of its admeasurement. But if an order be left to be executed, and time allowed to send to the manufactory at Ravenscroft, the glass is sent in sizes exactly corresponding to the order given, and will be charged as such only: this circumstance is of some importance when large quantities are required, as is not unfrequently the case at this time, when plate-glass is so much in fashion. The company often require three or four months to execute an order of any magnitude. The value of such kind of glass is very considerable in comparison of the other sorts, common sized squares for windows amounting from two to three pounds each, and sometimes, in French windows, as high as five pounds. It is, nevertheless, so much preferred at this time, that even our shop windows in the leading streets are daily becoming glazed with it.

There are also many other sorts of plate-glass in use, among these, that which is called German-sheet is the most esteemed; its colour is beautiful, being the most colourless of any made, but its outside appearance is disagreeable, arising from its appearing so uneven or wavy.

wavy. Indeed it resembles, on its outside, a substance which has been subjected to the hammer. The plate-glass seen in windows, of a red tint, was much in use about twenty years since, and is of German manufacture, and known among the glaziers as Bohemian plate-glass; its colour at first was calculated to strike, but colour is no recommendation to glass, and hence it is now almost quite laid aside.

Glaziers value their work by feet, inches, and parts, and the value of the glass increases as that of the size of its squares. Their charges are regulated by the Master and Wardens and Court-assistants of the Company of Glaziers, who are generally not very unmindful of themselves. The table of their present charges runs thus:—

	s.	d.
Best crown, in squares, not exceeding 3 ft. in each square	3	10
Ditto, ditto, 2 ft. 6 in. in each square . .	3	4
Ditto, ditto, 2 ft. ditto	3	2
Ditto, ditto, under 2 ft. ditto	3	0

Second crown, of similar proportions, is about 10 per cent. cheaper than the best crown.

And thirds, in a proportion of 10 per cent. still cheaper than the seconds.

Green-glass is the cheapest window glass made, and is put into new sashes at a price not exceeding eighteen pence per foot.

All kinds of bent-glass, for circular or other windows, varies in its price in proportion to its size and to the trouble in obtaining and fitting it in.

Cottage, and some kind of church-windows are glazed in squares, or other figures, in leaden rebates, such kind of glass, when so fitted in windows of the shape of a rhombus, are technically called "quarries." The lead for such windows is cast and drawn for the purpose, and purchased by the glaziers in packages by the cwt.; it is cut to the sizes and lengths required, and soldered together at their intersections: the leaden work is of various sizes in proportion to the strength of the work for which it is wanted. This metal, which is used instead of the cross-bars of sashes, is so soft as to be easily bent where the groove is left in it for the glass; one side or cheek of which is pressed down all round, the shape left in it for the glass by a small tool called a stopping-knife, and the quarry is put into the place so made for it, and, with the same tool, the side of the groove which had been thus bent down to admit it, is raised up to the quarry, and is afterwards smoothed close to it. These kind of windows are farther strengthened by vertical and cross bars of iron, to which the leaden ones are secured by bands soldered to the latter, and bent and twisted round the former; in cottage windows these bars are often of wood to which the bands are fastened in a similar manner.

Glaziers now cut all their glass out with the diamond, whereas formerly an iron was made use of for that purpose, called a grozing-iron: there is reason to believe that this process was tedious, and even difficult; and, perhaps, inapplicable to the separating of the plate-glass. The grozing-iron was an instrument made, in its shape, not unlike a key such as is used for the purpose of opening and shutting locks; it had wards in its sides which were applied to scratch the surface and snap off the part required to be separated. The diamond now in general use is as complete for this purpose as can possibly be wished, as, by drawing it merely over the glass to be cut, its surface becomes so regularly fractured as to allow, by a small pressure downwards, the piece operated upon to be easily removed, and that without much chance of accident. For this purpose, the diamond spark must be left in its natural state as found in the mines, as its principal virtue lies in its outward-coat. It is ascertained that when it is cut or polished it loses all its power in promoting the fracture on the glass. To make the diamond useful to the glazier, it is fixed in lead secured by a ferrule of brass, which is fastened to a handle of ebony or other hard wood, the whole together not assuming a size larger than a moderate sized drawing-pencil. The diamond, thus described, constitutes the principal working-tool of the glazier, and its scarcity renders its value to a journeyman of some little importance; some masters in this business supply their men with this tool, while others require them to find their own. The other tools which they use consist of a rule commonly of three feet in length, divided into thirty-six parts or inches, and each part or inch again divided into fractions. With this rule the squares and tables of glass are divided, and cut to the several sizes wanted. A glazier also wants several small straight-edges for the diamond to work against. A straight-edge consists merely of a thin piece of mahogany, or other hard wood, about two inches wide, and one-eighth of an inch in thickness, wrought quite parallel, having its faces right and left splayed off a little to allow of the diamond being drawn more correctly against its edge. They have also stopping-knives for bedding the glass in the wooden rebates of the sashes; a stopping-knife is no more than an instrument similar to a common dinner-knife reduced in the length of the blade to about three inches, and ground away on each of its edges till they approach to an apex. With this knife he smooths and spreads the putty to secure the glass in the sashes. In repairs of windows for broken squares, which the glazier calls "stopping in," or "squares stopped in," he makes use of another knife for the purpose of hacking out the old putty, and which is termed the "hacking-out tool," and consists literally of no more than an old broken knife ground sharp on its edge, and also at the end where it has been broken off from the rest of the blade. The old putty is cut out of the rebates by applying the hacking-out tool all round them, by striking it at its thickest or upper edge with a common small hammer until the whole of the old putty is removed, which, when done, the rebate of the sash is scraped and smoothed all round by the stopping-knife, and the new square of glass is cut into the sash, bedded in putty, and finished. The glazier also requires a pair of compasses made, in one of

of their legs, with a socket adapted to receive the handle of the diamond; with the compasses so prepared he draws and cuts out all the shapes of glass required for the glazing of fan-lights, or other circular portions of glass wanted in sashes.

The business of a glazier also includes cleaning the glass in windows in inhabited houses; this forms no inconsiderable portion of his trade in London, and many of the masters, when in a large way, keep one or more men constantly employed in it, the charge for which is regulated by the number of windows cleaned, or the number of squares in each sash. When the windows exceed twelve squares in each they are numbered and charged at per dozen, the price varying from 6d. to 8d. each dozen. When the sashes are folding, or what is better known as French-windows, the squares of glass in such sashes running much larger, a third more is charged for the cleaning of them than for the common windows. The master glazier takes the risk of breaking of glass by his men, when employed in this business.

There are in London several tradesmen known only as glass-cutters; their business embraces the cutting out of the glass only, which they retail in pieces or squares exactly to the size applied for, the parties purchasing undertaking of themselves the business of stopping them in.

The prices of the glaziers are very irregular when left to themselves to make their own charges. They adopt those of the Glaziers' Company usually, and it is from these charges which the surveyors regulate theirs from (or, as it is generally called, the measure and value); but glazing may be done (with a good profit to the glazier) at 15 per cent. less than either, and with glass as good, and as neatly and well cut in as it is generally by the master who adopts his charges from the Company's list of prices. Good glazing requires that all the glass be cut *full* into the rebates, that is, that the glass fill the void left for it in the sash completely. When the glass is cut too small, or even too large, it is easily broken by the pressure of the air from within, or by the wind from without; careless glaziers not unfrequently, when they have cut their glass too small, leave the putty projecting from the wood very full all round to hide this defect in their glazing, but no glazier who has any respect for his reputation would suffer glass so cut to be sent from out of his premises. The putty in no case should project beyond the line of the wood in the inside, or, more properly, the moulding side of the window; but should be exactly fair and level with it in every part. Large squares of glass should be firmly bedded in the rebate of the sash in putty of a moderate consistence in point of tempering, and when so bedded all round, small sprigs or tacks should be driven into the rebates to further secure it in the sash, and the whole should afterwards be further covered with another lining of putty spread quite smooth all round the rebate on the outside. Sashes, of whatever description they may be, should be once painted over, or, as it is called, primed, before they are put into the hand of the glazier, as the putty will be more firm and durable by adopting such a previous priming.

Lately there has been a considerable additional duty on glass, amounting in the way in which the public are charged for it to at least 20 per cent.; the prices before recited embrace this additional rate. Every consumer of glass when in want of a large quantity, should, previously to giving his order to the glazier, specially agree for its price and also quality; for the latter purpose, to name particularly of what kind of glass the windows are to be glazed, referring to the sashes themselves for their sizes; by sending to several of the trade for an estimate of the price in this manner, he will get his work performed at a value far below the usual or Company's price. It should, however, be observed that what is said of the glazier, in this respect, is applicable to every other branch of the building business.

In the decoration of the windows of our churches, for which the zeal and piety of our ancestors were so remarkable, and in which they arrived at so great a degree of perfection in having produced colours on glass at once of superior beauty and brilliancy to any thing since accomplished, the superior excellence in their colours was retained in all its splendour through the several reigns antecedent to that of Elizabeth; after which, and in consequence of the interdiction of art from the then cherished opinions of their works being idolatrous, and in no way conformable to the spirit of the religious notions then taking effect by the reformation, it began to fail. The ruby-coloured glass, so much esteemed at this time, began to disappear at that period, and did completely so during the reign of her successor James I. Many attempts have been since made to recover it, but the trials and expenses attending them having been tedious and enormous, has deterred the artists from yet having successfully followed up its pursuit, in consequence of which no glass of the ruby kind is now manufactured.

The value of painted windows, as has been before observed, will entirely depend on their design, and the variety of colours to be introduced in them. Some curious estimates of the expense of such windows, as they were executed for the sumptuous chapel in King's College, at Cambridge, may be seen in the Appendix to Britton's Architectural Antiquities of Great Britain, which is made for eighteen windows of the upper story of the chapel, and runs thus, viz. that the work is agreed to be executed "with good, clene, sure and perfytte glasse, and oryent colours, and *imagery*." These to be equal to the windows of the King's New Chapel, at Westminster: Six of the windows to be finished within twelve months, and the other twelve windows within four years. To bind all the windows "with double bands of leade for defence of great wyndes and outragious wethering, after the rate of two-pence evry ffootte," the glass to be 16 pence per foot. The glaziers ("Williamson and Symondes") to the work were bound to perform the conditions of the indenture under a penalty of 500 "markes sterlinges."

GOLD-

GOLD-BEATING AND GILT-WIRE DRAWING.

The business of the gold-beater is to reduce solid gold and silver into what is denominated leaf-gold and silver, though the metals in this state are many degrees thinner and finer than any leaf whatever. Gold and silver leaf is absolutely necessary in many other trades, and it will be our business in this article to explain the method by which the solid and dense substance is reduced to this state of almost inconceivable thinness, in which, notwithstanding its specific gravity, it will float in the air like a feather.

Gold in itself, and when very pure, is soft, easily cut or graved, and so tough, that when at length made to break by repeated bendings, backwards or forwards, the fracture on each of the pieces, appears drawn out like a wedge.

The colour of pure gold, by reflected light, is a full bright yellow, tending on one hand towards orange, and, on the other, towards a brass yellow. Gold fused with borax becomes paler than usual, but when fused with nitre it becomes more highly coloured; hence, as this metal is reckoned beautiful in proportion to the fulness and brilliancy of its colour, the borax flux used by goldsmiths is generally mixed with a sufficient quantity of nitre to counterbalance its discolouring property. The colour of gold, when in high fusion, is of a bluish green, of a similar tint with that of gold by transmitted light: this latter may be observed by laying a leaf of gold between two thin plates of colourless glass, and holding it between the eye and a strong light.

The great value which has at all times been fixed on gold, its beautiful colour, incorruptibility, and great compactness, render its ductility an object of vast importance. On this depend sundry arts and manufactures, in which the solid mass is extended to an astonishing tenuity, and variously applied on the surface of other bodies, as well for ornament as preservation.

The gold, in preparation for the leaf, is melted in a black-lead crucible, with some borax, in a wind furnace: as soon as it is in perfect fusion, it is poured into an iron ingot-mould, six or eight inches long, and three-quarters of an inch wide, previously greased and heated, so as to make the tallow run and smoke, but not to take flame. When the gold is fixed and solid it is made red-hot to burn off the unctuous matter, and then forged on an anvil into a long plate, which is still further extended by being passed frequently between polished steel rollers, till it becomes no thicker than a ribbon or a sheet of paper. Formerly, the whole of this process was done by means of the hammer; but the use of the flatting-mill abridges the operation, and renders the plate of a more uniform thickness. The plate, or, as it is sometimes called, the ribbon, is divided by compasses, and cut with shears into equal pieces, which, consequently, are of equal weights: these are now forged on the anvil till they are an inch square, and afterwards well annealed to correct the rigidity which the metal has contracted in the hammering and flatting. Two ounces of gold, or 960 grains, make an hundred and fifty of these squares, whence each plate weighs little more than six grains, they are found to be about the $\frac{1}{760}$th part of an inch thick, that is, about 760 such leaves placed upon each other, and pressed close together, would take up in thickness only an inch. To proceed in the extension of these small plates it is necessary to interpose some smooth body between them and the hammer, for the purpose of softening the blow, and defending the gold from its immediate action, as also to place between every two of the plates some intermediate substance, which, while it prevents their uniting together, or injuring one another, may suffer them freely to extend. These objects are attained by means of certain animal membranes.

Gold-beaters make use of three kinds of membranes, viz. for the outside cover, common parchment made of sheep-skin is used; for interlaying with the gold, first, the smoothest and closest vellum, made of calves-skin; and, afterwards, the much finer skins of ox-gut, stript off from the large straight gut slit open, curiously prepared for the express purpose, and hence called gold-beaters' skin. According to Dr. Lewis, the preparation of these last is a distinct business, practised only by two or three persons in the kingdom. The general process is supposed to consist in applying them one upon another, by the smooth sides, in a moist state, in which they readily cohere and unite inseparably, stretching them very carefully on a frame, scraping off the fat and rough matter, so as to leave only the fine exterior membrane of the intestine, at the same time beating them between double leaves of paper, to force out what grease may remain in them, and then drying and pressing them. Notwithstanding the vast extent to which gold is beaten between these skins, and the great tenuity of the skins themselves, they yet sustain continual re-

petitions of the process for several months, without appearing to extend or grow thinner.

The beating of gold is performed on a smooth block of black marble, of a weight from two to four or five hundred weight; the heavier it is the better it is adapted to the purpose for which it is employed. It is about nine inches square on the upper surface, and sometimes less, fitted into the middle of a wooden frame about two feet square, so as that the surface of the marble and the frame form one continuous plane. Three of the sides are furnished with a high ledge, and the front, which is open, has a leathern flap fastened to it, which the gold-beater makes use of as an apron, for preserving the fragments of gold that fall off. Three hammers are employed, each of which is furnished with two round and somewhat convex faces, but the workman in general uses only one of these faces. The first is called the catch-hammer, is about four inches in diameter, and weighs from fifteen to twenty pounds; the second, called the shodering-hammer, and weighs about twelve pounds: the third, called the gold or finishing hammer, weighs ten pounds. The French make use of four hammers, differing in size and shape from those of our workmen. They have only one face, being, in figure, truncated cones; the first has very little convexity, is five inches in diameter, and weighs fourteen pounds; the second is more convex than the first, and only about half its weight; the third is still more convex, weighs about four pounds, and is only two inches wide. The fourth, or finishing-hammer, is nearly as heavy as the first, but narrower by an inch, and is the most convex of all.

A hundred and fifty of the pieces of gold are interlaid with leaves of vellum, three or four inches square, one leaf being placed between every two of the pieces; and there are about twenty other of the vellum on the outsides, over these is drawn a parchment case, open at both ends, and over this another in a contrary direction, so that the gold and vellum are kept tight and close on all sides. The whole is beaten with the heaviest hammer, and occasionally turned upside down till the gold is stretched to the extent of the vellum; the case being from time to time opened to ascertain how the extension goes on, and the packet is, sometimes, bent and rolled, as it were, between the hands, for procuring sufficient freedom to the gold, or, to use the workmen's phrase, "to make the gold work." The pieces, when extended to the size of the vellum, are taken out from between the vellum-leaves, and cut into four with a steel knife, and the 600 divisions are interlaid in the same manner with pieces of the ox-gut skins five inches square. The beating is again repeated with a lighter hammer, till the golden plates have again acquired the extent of the skins: they are now a second time divided into four, but the instrument used for this purpose is a piece of cane cut to a very thin edge, the leaves, in this stage of the business being so light, that the moisture of the air or breath, condensing on a metal knife, would occasion them to stick to it. These last divisions are now too numerous to admit of thei being beaten at once, they are parted into three parcels which are beaten separately, with the smallest hammer, till they are stretched for the third time to the size of the skins; they are now reduced to the greatest thinness they will admit of, though it is said that the French carry the business one step farther. In the beating, the process, however simple, appears to require a good deal of address, in order to apply the hammers so as to extend the metal uniformly from the middle to the sides; a single improper blow is apt, not only to break the gold leaves, but to cut the skins. After the last beating, the leaves are taken up by the end of a cane instrument, and being blown flat on a leather cushion, are cut to a size, one by one, with a square frame of cane made of a proper sharpness; they are then fitted into books of twenty-five leaves each, the paper of which is well smoothed, and rubbed with red-bole to prevent their sticking to it.

The process of gold-beating is considerably influenced by the weather. In wet weather, the skins grow damp, which renders the operation more tedious. A frosty season is still more injurious to it, the cold affecting the metallic leaves themselves so that they cannot be easily blown flat, but break, wrinkle, or run together.

Gold-leaf ought to be prepared from the finest gold, as any alloy, however small, would injure the colour and make it too hard for working. But though the gold-beater cannot advantageously diminish the quantity of gold in the leaf by the mixture of any other substance with the gold, yet methods have been devised for saving the precious metal, by producing a kind of leaf called party-gold, whose basis is silver, and which has only a superficial coat of gold on one side: this is done by placing upon one another a thick leaf of silver and a much thinner one of gold, and being heated and pressed together, they unite and cohere; and being then beaten into fine leaves, as in the process already described, the gold, though it is in quantity only about one-fourth of that of the silver, continues every where to cover it, the extension of the former keeping pace with that of the latter.

We shall now proceed to speak of the preparation for gilt-wire. What is called gold-wire, or gilt-wire, has only an exterior covering of gold, the internal part being silver. A rod of silver, above an inch thick, two feet in length, and weighing about 20 lbs., is coated with gold, and then reduced into wire, by drawing it successively through a number of holes, made in steel plates, diminishing almost insensibly in regular degrees. The purity of gold employed for this use is a point of great importance, for on this depends the beauty and the durability of colour when wrought into laces, brocades, and other articles of consumption. With respect to the silver, which makes up the internal body of the wire, its fineness is of less importance; it is said to be even better when it is alloyed, because very fine silver, when annealed in the fire, becomes so soft as to suffer

suffer the golden coat, in some measure, to sink in it, and hence the admixture of a little copper communicates to it a sufficient degree of hardness for preventing this inconvenience. The gold is employed in thick leaves, prepared for the purpose, which are applied all over the silver rod, and pressed down smooth with a steel burnisher. Several of the gold leaves are laid over one another, according as the gilding is required more or less thick. The smallest proportion allowed is 100 grains of gold to a pound of silver, or 5,760 grains. The largest proportion for the best double gilt wire, was, formerly, 120 grains to a pound; but it is probably a good deal increased.

The beginning of the process, as well as the preparation and gilding of the silver rod, is performed by the refiner, who uses plates of hardened steel with a piece of tough iron welded on the back to prevent the steel from breaking. In this back part the holes are much wider than the corresponding ones in steel, and of a conical shape; partly, that the rod may not be scratched against the outer edge, and partly for receiving some bees-wax, which makes the rod pass more easily, and preserves the gold from being rubbed off. The plate being properly secured, one end of the rod, made somewhat smaller than the rest, is pushed through such a hole as will admit of it; and being taken hold of by pincers, adapted to the purpose, whose chaps are toothed somewhat like a file, to keep the rod from slipping out by the violence necessary for drawing it out, the handles or branches of the clamps are bent upwards, and an iron loop put over the curvature, so that the force, which pulls them horizontally by the loop, serves at the same time to press them together. To the loop is fastened a rope, the farther end of which goes round a capstan, or upright cylinder with cross-bars, which requires the strength of several men to turn it. The rod, thus drawn through, is well annealed, then passed in the same manner through the next hole, and the annealing and drawing repeated, less and less force sufficing as it diminishes in thickness. When reduced to the size of a quill, it is delivered in coils to the wire-drawer. The remainder of the process requires plates of a different quality, those made of steel being apt to fret the wire, and strip off the gold. There are two sorts of these plates, one of considerable thickness, for the wire in its larger state, the other only about half as thick, for the finer wire, where less force is sufficient in drawing. These plates, though, in a measure, rather brittle, have sufficient toughness to admit of the holes being beaten up, or contracted, by a few blows of a hammer; so that when any of them have been widened by a length of wire being drawn through, they are thus reduced again to the proper dimensions for preserving the gradation. The holes, after each beating up, are opened by a long slender instrument, called a point, made of refined steel; one end of which, to the length of about five inches, is round, and serves as a handle; the rest, about twice as long, is square, and tapered to a fine point. The first holes being so far worn, as to be unfit for bearing further reductions, the next to them, grown likewise wider, supply their places, and are themselves successively supplied by those which follow; of course, as each plate is furnished with several more of the same holes than are wanted at first, it continues to afford a complete series, after a considerable number of the larger has become unserviceable. Great part of the dexterity of the workman consists in adapting the hole to the wire; that the wire may not pass so easily, as not to receive sufficient extension, or so difficultly as to be broken in the drawing. For determining this point with greater certainty than could be done from the mere resistance of the wire, he uses a brass plate called a size, on which is measured, by means of notches, like stops, cut at one end, the increase which a certain length of wire should gain in passing through a fresh hole: if the wire is found to stretch too much or too little, the hole is widened or contracted. As the extension is adjusted by this instrument, there are others for measuring the degree of fineness of the wire itself. Slits of different widths, made in thick polished iron rings, serve as gauges for this use.

The wire-drawer's process begins with annealing the large wire received from the refiner; this is performed by placing it coiled up on some lighted charcoal in a cylindrical cavity called the pit, made for this purpose, under a chimney, about six inches deep, and throwing more burning charcoal over it; the pit having no aperture at bottom to admit air, the fuel burns languidly, affording only sufficient heat to make the metal red-hot, without endangering its melting.

Being then quenched in water for the sake of expedition in cooling it, though the metal would doubtless be softened more effectually if suffered to cool leisurely, one end of it is passed through the first hole in the thick plate, and fastened to an upright wooden cylinder, six or eight inches in diameter: in the top of the cylinder are fixed two staples, and through these is passed the long arm of a handle, by which the cylinder is turned on its axis by several men. In the continuation of this part of the process, the wire is frequently annealed and quenched, after passing through every hole or every other hole, till it is brought to about the size of the small end of a tobacco-pipe; and in this state it is cut into portions for the fine wire-drawer.

In this last part of the wire-drawing process, annealing is not needful; but it is still as necessary as before to wax the wire at every hole. Much less force being now sufficient for drawing it through the plate, a different instrument is used. A kind of wheel or circular piece of wood, much wider than the foregoing cylinder, is placed horizontally in its upper surface and some small holes at different distances from the axis, and into one or another of these, according to the force required, is occasionally inserted the point of an upright handle, whose upper end is received in a hole made in a cross bar above. From this the wire

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is wound off upon a smaller cylinder called a rocket, placed on the spindle of a spinning-wheel; and this last cylinder being fixed on its axis behind the plate, the wire is again drawn through upon the first; and being at length brought to the proper fineness, it is annealed to fit it for the flatting-mill. This annealing is performed in a different manner from the foregoing ones, and with much less heat; for if the wire was now made red-hot it would wholly lose its golden colour, and become black, bluish, or white, as is often experienced in different parcels of gilt wire. Being wound upon a large hollow copper bobbin, the bobbin is set upright, some lighted charcoal or small-coal placed round it and brought gradually nearer and nearer, and some small-coal put in the cavity of the bobbin, the wire being carefully watched, that as soon as it appears of a proper colour it may be immediately removed from the heat. This is an operation of great nicety, and is generally performed by the master himself. The wire, though it in good measure retains the springiness which it had acquired in the drawing, and does not prove near so soft as it might be made by a greater heat, is nevertheless found to be sufficiently so for yielding with ease to the flatting mill.

The flatting-mill consists of two rolls, turned in a lathe to a perfect roundness, exquisitely polished, placed with their axis parallel one over another, set by screws till their circumferences come almost into contact, and both made to go round by one handle; the lowermost is about ten inches in diameter, the upper commonly little more than two, though some make it considerably larger; and indeed it would be more convenient if made as large, or nearly so, as the lower; their width or thickness is about an inch and a quarter. The wire unwinding from a bobbin, and passing first between the leaves of an old book pressed by a small weight, which kept it somewhat tight, and then through a narrow slit in an upright piece of wood called a ketch, which gives notice of any knot or doubling, is directed by means of a small conical hole in a piece of iron called a guide, to any particular part of the width of the rolls, that if there should be any imperfection or inequality of the surface the wire may be kept from those parts; and that when one part is soiled by the passage of a length of wire, the wire may be shifted till the whole width of the rolls is soiled, so as to require being cleaned and polished anew with the fine powder called putty, prepared by calcining a mixture of lead and tin: the workmen value the rolls from the number of threads they will receive, that is, from the number of places which the wire can thus be shifted to; good rolls will receive forty threads. The wire flatted between the rolls is wound again as it comes through, on a bobbin, which is turned by a wheel fixed on the axis of one of the rolls, and so proportioned that the motion of the bobbin just keeps pace with that of the rolls.

The vast extent to which gold is apparently stretched in the foregoing operations, has induced several persons to make experiments for determining its exact degree by mensuration and weight. In an experiment of Reaumur's, forty-two square inches and three tenths of gold leaf weighed one grain troy; and Mr. Boyle found that fifty and seven-tenths weighed but a grain. The thickness of the gold leaf examined by the one was the 207,355th, and of that by the other only the 248,532nd part of an inch.

Dr. Halley found, that of superfine gilt-wire six feet weighed a grain: M. de Reaumur makes about four inches more go to the same weight; and Mr. Boyle is said, if there be no error in the numbers, to have had gilt-wire much finer than any of these. Allowing six feet to make a grain, and the proportion of gold to be that commonly used by our wire-drawers; the length to which a grain of gold is extended on the wire, comes to be nearly 352 feet.

In flatting, the wire is extended, according to M. de Reaumur, one-seventh part of its length, and to the width of one ninety-sixth of an inch; in some trials that have been made by the workmen, the extension in length appeared less, but that in breadth so much greater that the square extension was at least equal to that assigned by Reaumur. Hence one grain of gold is stretched on the flatted wire to the length of above 401 feet, to a surface of above 100 square inches, and to the thinness of the 492,090th part of an inch.

M. de Reaumur carries the extension of gold to a much greater degree. He says the wire continues gilded when only one part of gold is used to 360 of silver, and that it may be stretched in flatting one-fourth of its length, and to the width of one forty-eighth of an inch. In this case, a grain of gold must be extended upwards of a mile, and cover an area of 1,400 square inches. He computes the thickness of the golden coat in the thinnest parts of some gilt wire to be no more than the 14000,000th part of an inch, so that it is only about a hundredth part of the thickness of gold leaf.

Yet notwithstanding this amazing tenuity, if a piece of the gilt wire be immersed in warm aquafortis, which will gradually dissolve and eat out the silver, the remaining golden coat will still hang together, and form, while the fluid prevents it from collapsing, a continuous opaque tube. To succeed in this experiment, the aquafortis must not be very strong, nor the heat great; for then the acid, acting hastily and impetuously upon the silver, would disunite the particles of the gold.

Whether any other metal can be extended to an equal degree is not yet clear, for as it is the great value of gold which engages the workmen to endeavour as much as possible to stretch it to the largest surface, the same efforts have not been made in regard to the less valuable metals: to make a fair comparison, trial should be made of extending silver upon the surface of gold in the same manner as gold is extended upon silver. It may be observed also, that as gold is nearly as heavy

heavy again as silver, or contains nearly double the quantity of matter under an equal volume, so, if equal weights of the two metals be stretched to equal extents, the silver will be little more than half the thinness of the gold; and conversely, if silver could be brought to equal tenuity with gold in regard to bulk, it would, in regard to quantity of matter, be nearly of double extensibility.

There are various methods of applying the gold thus extended, to cover the surface of other bodies. For laces and brocades, the flatted gilt-wire is spun on threads of yellow silk, approaching as near as may be to the colour of gold itself. The wire, winding off from a bobbin, twists about the thread as it spins round, and by means of curious machinery, too complex to be described here, a number of threads is thus twisted at once by the turning of one wheel. The principal art consists in so regulating the motion, that the several circumvolutions of the flatted wire on each thread may just touch one another, and form as it were, one continued covering.

It is said that at Milan there is made a sort of flatted wire gilt only on one side, which is wound upon the thread, so that only the gilt side appears; and that the preparation of this wire is kept a secret, and has been attempted in other places with little success. There is also a gilt copper wire, made in the same manner as the gilt silver. Savary observes, that this kind of wire, called false gold, is prepared chiefly at Nuremburg; and that the ordinances of France require it to be spun, for its distinction of the gilt silver, on flaxen or hempen threads. One of our writers takes notice, that the Chinese, instead of flatted gilt-wire, use slips of gilt paper, which they interweave in their stuffs and twist upon silk threads: this practice he inconsiderately proposes as a hint to the British weaver. Whatever be the pretended beauty of the stuffs of this kind of manufacture, it is obvious that they must want durability. The Chinese themselves, according to Du Halde's account, sensible of this imperfection, scarcely use them any otherwise than in tapestries, and such other ornaments as are not intended to be much worn or exposed to moisture.

Paper, wood, and other like subjects are gilded by spreading upon them some adhesive substances, and when almost dry, so as but just to make the gold stick, applying gold or gilt leaf, and pressing it down with a bunch of cotton or the bottom of a hare's foot: when grown thoroughly dry the superfluous or loose gold is wiped off, and the fixed golden coat burnished with a dog's tooth or with a smooth piece of agate or pebble. Different kinds of adhesive matters are employed for this use: where resistance to rain or moisture is required, oil paints; in most other cases a size, made from the cuttings of parchment or white leather by boiling them in water.

GUN-MAKING.

The business of the gun-smith is the manufacturing of fire arms of the smaller sort, as muskets, fowling pieces, pistols, &c. The principal part of all these instruments is the barrel, which, however, is not made by those who call themselves gun-smiths, but by persons who forge them in a large way, and who have forges and premises adapted to the business; the forges used by gun-smiths being on a much smaller scale than those required for the manufacture of the barrels. Besides among gun-smiths we find great attention paid to the division of labour: one man or set of men, for instance, is employed in what is termed the boring, though, in truth, the barrels are formed at first with a bore throughout, but not with that accuracy which is required for these kind of instruments: other persons are employed to file and polish the outside of the barrel; to some is allotted the business of making and fixing the breech, the touch-hole, &c.: others forge the gun-locks in a rough way, and others are employed to file, polish, and put together the several parts of which the locks are composed, &c. By the attention and civility of Mr. W. H. Mortimer, of Fleet-street, we have had an opportunity of examining the several departments of this manufacture, and shall endeavour to describe them in a familiar manner to our readers, noticing, in the course of the article, certain inventions for which His Majesty's letters patent have been obtained.

The barrel, which we are first to describe, ought to possess the following properties: *lightness*, that it may incommode the person who carries it as little as possible, and *strength*, to enable it to bear a full charge without any risk of bursting: it ought to be constructed so as not to *recoil* with violence, and it ought to be of

sufficient length to carry the shot or bullet to as great a distance as the force of the powder employed is capable of doing.

The imperfections to which a gun-barrel is liable in forging are of three sorts, viz. the *chink*, the *crack*, and the *flaw*: the chink is a solution of continuity, running lengthwise of the barrel: the crack is more irregular in its form than the chink, and running in a transverse direction or across the barrel: the flaw differs from both; it is a small plate or scale which adheres to the barrel by a narrow base, from which it spreads out as the head of a nail does from its shank; and when separated, leaves a pit or hollow in the metal. The chink and the flaw are of much greater consequence than the crack, as the effort of the powder is exerted upon the circumference, and not upon the length of the barrel. The flaw is more frequent than the chink: when external and superficial, they are all three defects in point of neatness only; but when situated within the barrel, they are of material disadvantage by affording a lodgment to moisture and foulness that corrode the iron, and thus continually enlarge the excavation until the barrel bursts or at least becomes exceedingly dangerous to use. The crack is of but little consequence if near the muzzle of the barrel; but if at the breech end it should never be attempted to be mended, and indeed by respectable manufacturers, such as the gentleman alluded to, never is. We shall now proceed to describe the several parts of the gun, beginning with the barrels.

To form a gun-barrel in the manner generally practised for those denominated common, the workmen begin by heating and hammering out a bar of iron into the form of a flat ruler, thinner at the end intended for the muzzle, and thicker at that for the breech; the length, breadth, and thickness of the whole plate being regulated by the intended length, diameter, and weight of the barrel. This oblong plate of metal is then, by repeated heating and hammering, turned round a cylindrical rod of tempered iron, called a mandril, whose diameter is considerably less than the intended bore of the barrel. The edges of the plate are made to overlap each other about half an inch, and are welded together by heating the tube in lengths of two or three inches at a time, and hammering it with very brisk but moderate strokes, upon an anvil which has a number of semicircular furrows in it, adapted to the various sizes of barrels. The heat required for welding is the bright white heat, which immediately precedes fusion, and at which the particles of the metal unite and blend so intimately with each other, that, when properly managed, not a trace is left of their former separation: this degree of heat is generally known by a number of brilliant sparks flying off from the iron whilst in the fire; although it requires much practice and experience to ascertain the degree of heat required for welding iron, which possesses various qualities, and is seldom alike. Every time the barrel is withdrawn from the forge, the workman strikes the end of it once or twice gently against the anvil in a horizontal direction: this operation serves to consolidate the particles of the metal more perfectly, and to obliterate any appearance of a seam in the barrel. The mandril is then introduced into the bore or cavity; and the barrel, being placed in one of the furrows or moulds of the anvil, is hammered very briskly by two persons besides the forger, who all the time keeps turning the barrel round in the mould, so that every point of the heated portion may come equally under the action of the hammers. These heatings and hammerings are repeated until the whole of the barrel has undergone the same operation, and all its parts are rendered as perfectly continuous as if it had been bored out of a solid piece. For better work the barrel is forged in separate pieces of eight or nine inches in length, and then welded together lengthwise as well as in the lapping over. The other mode being the easiest done, and the quickest, is the most usual.

The barrel, when forged, is either finished in the common manner, or made to undergo the operation of twisting, which is a process employed on those barrels that are intended to be of a superior quality and price to others. This operation consists in heating the barrel in portions of a few inches at a time, to a high degree of red-heat; when one end of it is screwed into a vice, and into the other is introduced a square piece of iron with a handle like an augur, and by means of these the fibres of the heated portion are twisted in a spiral direction, that is thought to resist the effort of the powder much better than a longitudinal one. Pistol barrels that are to go in pairs, such as duelling pistols, are forged in one piece, and are cut asunder at the muzzles after they have been bored; by which there is not only a saving of iron and of labour, but a certainty of the caliber being perfectly the same in both. The next operation consists in giving to the barrel its proper caliber; this is termed boring, which is done in the following manner. Two beams of very strong wood, as oak, each about six inches in diameter, and six or seven feet long, are placed horizontally and parallel to one another, having their extremities mortised upon a strong upright piece about three feet high, and firmly fixed. A space of from two to four inches is left between the horizontal pieces, in which a piece of wood is made to slide, by having at either end a tenon let into a groove which runs on the inside of each beam throughout its whole length. Through this sliding piece a strong pin or bolt of iron is driven or screwed in a perpendicular direction, having at its upper end a round hole large enough to admit the breech of the barrel, which is secured in it by means of a piece of iron that serves as a wedge, and a vertical screw passing through the upper part of the hole. A chain is fastened to a staple on one side of the sliding piece which runs between the two horizontal beams, and passing over a pulley at one end of the machine, has a weight hooked to it. An upright piece of timber is fixed above this pulley and between the end of the beams,

beams, having its upper end perforated by the axis of an iron crank furnished with a square socket; the other axis being supported by the wall or by a strong post, and loaded with a heavy wheel of cast iron to give it force. The axes of the crank are in a line with the hole in the bolt already described. The borer being then fixed into the socket of the crank, has its other end previously well oiled, introduced into the barrel, whose breech part is made fast in the hole of the bolt: the chain is then carried over the pulley, and the weight hooked on: the crank being then turned with the hand, the barrel advances as the borer cuts its way till it has passed through the whole length.

The boring-bit is a rod of iron somewhat longer than the barrel; one end being made to fit the socket of the crank, and the other being furnished with a cylindrical plug of tempered steel, about an inch and a half in length, and having its surface cut in the manner of a perpetual screw, the threads being flat, about a quarter of an inch in breadth, and running with very little obliquity. This form gives the bit a very strong hold of the metal; and the threads being sharp at the edges, scoop out and remove every roughness and inequality from the inside of the barrel, and render the cavity smooth and equal throughout. Only two of the threads are brought into action, the others being prevented from touching the barrel by tying on one side a piece of wood, of almost any kind, which is called a spill.

A number of bits, each a little larger than the preceding one, are afterwards successively passed through the barrel in the same way until it has acquired the intended caliber. The equality of the bore is so essential to the excellence of a piece, that the greatest accuracy in every other particular will not compensate for the want of it. With regard to this, every thing almost depends on the eye of the workman: he chooses a good light for his business, and discovers in an instant if there be the smallest defect. To a stranger looking through a finely bored barrel, with a proper light, an optical illusion presents itself, the farther end does not appear to be open throughout as it really is, but to have a small, but perfectly circular hole, in the centre of a finely polished mirror. Another observation worth noticing is, that though the bore of the barrel is perfectly even and straight, yet that during the process of boring it has a continual motion, which to a by-stander seems quite sufficient to throw it out of the straight line. The barrel may be now considered as quite finished with regard to its inside: at least it has nothing more to be done to it by the maker, after which it is in a condition to receive its proper form and proportions externally by means of the file. To do this with accuracy, four flat sides or faces are first formed; then eight, then sixteen, and so on, until it is made quite round, except the reinforced part, which in most of the modern work is left with eight sides. This octagonal form is certainly more elegant than the round one formerly in use: but it adds to the weight of the barrel without increasing its strength; for the effort of the powder will always be sustained by the thinnest part of the circumference without any regard to those places that are thicker than the rest.

It is absolutely necessary to the soundness of a barrel, that it should be of an equal thickness on every side; or, in the language of the workmen, a barrel ought to be perfectly upright. In order to arrive as nearly as possible to this perfect equality, the gunsmiths employ an instrument which they call a compass. It consists of an iron rod, bent so as to form two parallel branches about an inch distant from each other. One of these branches is introduced into the barrel, and kept closely applied to the side by means of one or more springs with which it is furnished: the other branch descends parallel to this, on the outside, and has several screws passing through it with their points directed to the barrel. By screwing these until their points touch the surface of the barrel, and then turning the instrument round within the bore, it is seen where the metal is too thick, and how much it must be reduced in order to render every part of the barrel perfectly equal throughout its circumference.

Before we proceed in the work of the gun, we may notice a patent invention for the manufacture of gun-barrels by Mr. Bradley.

This invention consists in the manufacturing of iron skelps for making barrels for fire-arms, wholly and entirely by rollers instead of by forge-hammers, which is the present mode of making them. For this purpose Mr. Bradley takes a pair of rollers about fifteen inches in diameter, which have been previously drilled and turned with four grooves requisite for manufacturing the sort of skelps required, and fixes them in such a frame as is generally used in working rollers. He then takes a bar of iron cut to the proper weight, as wide as the breech-end of the skelp required, which is heated in an air-furnace to what is called a welding heat, and puts it in the first instance through a groove in the roller. By this process the groove is cut or hollowed out in such a manner as to give out or produce the bar or piece of iron four inches wide at one end, and, by a gradual diminution, two inches and a half at the other. The bar must then be passed successively through three grooves formed similar to each other in principle, but cut in such a manner as after being passed through each of them gradually to bring the skelp to its proper form and size. These grooves are turned and chipped in such a manner as to make the bar or piece of iron after it has passed through them and is become a skelp, four inches and one-eighth wide at the breech and three-eighths of an inch thick, and three inches and one-eighth wide and barely three-sixteenths of an inch thick at the other end. The edges are made thinner than the middle, which is left, as the welders term it, thick on the back; and being in every respect of the proper dimensions for finished

finished skelps, they are thus produced by the rollers only without the aid of hammers, shears, or cutters, or any other machinery or implement whatever.

The advantages stated by the patentee of this invention over the common mode, is, that the barrels made from them turn very sound and clear, and are free from flaws: when welded they grind and bore much clearer than hammered ones. The pure metallic particles being compressed by the rollers both edge-ways and flat-ways at the same time, cohere more closely together; nor are the skelps liable to reins or flaws as those are which are edged up in a less hot state under a forge hammer. Barrels from these skelps will stand a much stronger proof than those from forged ones.

We shall also notice an improvement in the manufacture of barrels of all descriptions of fire-arms, made by Messrs. James and Jones of Birmingham, and for which they have obtained His Majesty's letters patent. This improvement may be thus described: the patentees take a skelp or piece of iron adapted for the purpose of making barrels for fire-arms which is to be brought into a form proper for welding, and then heated in a furnace so constructed as to give a regular welding heat to one half of the barrel at a time; and when heated sufficiently, the mandril or stamp is to be put expeditiously into it, and the barrel placed or held on a grooved anvil, upon which several hammers worked by steam are caused to fall or strike with great velocity upon such portions of the barrel desired to be welded, and when sufficiently welded the stamp is to be withdrawn. The number, weight, and velocity of the hammers may be varied according to the description of the barrel desired. They should be ranged in a straight line side by side, as true and as close together as they will work free, and cover a space in length of about twenty inches and in width four or five: they should work very true, and to do so they may be fixed, connected and worked by machinery. Or, instead of welding the barrels by hammers the same thing may be done between a pair of rollers grooved to fit the form of the barrel, the rollers having either an alternate or rotary motion and worked by steam, water, or other mechanical powers, but the hammer seems to be best as making the soundest and most perfect barrels. The great advantage of this method above others is, that the barrels are made sounder and more expeditiously than they can be by the common method. The invention extends also to the turning of barrels in an improved turning machine or lathe, with cutters or sharp steel instruments or tools, worked by machinery with steam, water, &c. The patentees give in their specification a full description of this new invented lathe, which they say may be made of cast iron, or of any other metal or substance adapted for the purpose.

The principal and advantages of this invention of turning barrels, &c. by the lathe worked by steam, &c. are, that when the barrel is fixed in its place it is turned without any farther aid or assistance from the workmen, by which means one more skilful foreman and an assistant may attend three or four turning machines or lathes, and finish a great number of barrels ready for filing much more perfect and true than they can be done by grinding, or by any other method now in use with the same power and manual labour. Ground barrels are very frequently unequal sided, one side having twice the substance of metal as the other; but by this new method they are more equal, and consequently much stronger with the same weight of metal than if the barrel were unequal; and when the barrel is set right a more certain and much better aim may be taken. "These," say the patentees, "we consider great advantages in the use and value of a musket or other barrel. We also do away with the use of expensive grindstones, from which dangerous accidents very frequently happen, and the necessity of grinding the barrels which is at all times a laborious, dangerous, and unhealthy business, whereas our method of turning barrels is comparatively a safe, easy, and healthful occupation."

To form the screw in the breech-end of the barrel, the first tool employed is a plug of tempered steel, somewhat conical, and having upon its surface the threads of a male screw. This tool, which is termed a screw-tap, being introduced into the barrel, it is turned from left to right and back again, until it has marked out the three or four first threads of the screw: another less conical tap is then introduced, and when this has carried on the impression of the screw as far as it is intended to go, a third tap is employed, which is nearly cylindrical, and scarcely differs from the plug of the breech which is intended to fill the screw thus formed in the barrel. The breech-plug has its screw formed by means of a screw-plate made of tempered steel, and has several female screws corresponding with the taps employed to form that in the barrel. A plug of seven or eight threads is sufficiently long, and the threads ought to be neat and sharp, so as to fill completely the turns made in the barrel by the tap. The breech-plug is afterwards case-hardened, or has its surface converted into steel by being covered over with shavings of horn or pairings of horse-hoof, and kept red hot in the fire for some time, after which it is plunged into water.

It should be observed that the breeching of a gun is of considerable importance in its shooting well. Almost every maker has a breech of his own contrivance: it consists of a male screw to fit the female one made in the barrel; a centre-hole or chamber, and an antichamber. The outside circumference may be made of any shape or form. The advantages arising from this kind of breeching over that formerly used are, that the shot are thrown in a more perfect direction and with greater velocity; that the barrel is much less subject to grow partially foul: that it is safer and goes off more instantaneously, and also that it causes the whole powder to inflame. It was customary with the gun-smiths in France to solder on the loops and the aim before they breeched the barrel. The English never restrict themselves

themselves to this, making use of soft solder only for this purpose. While the French use hard solder that requires great heat, which is apt to injure the inside so much as to require a repetition of fine-boring.

The last operation is that of colouring the barrel, previously to which it is polished with fine emery and oil, until it presents to the eye, throughout its whole length, and in whatever direction we observe it, a perfectly smooth, equal, and splendid surface. Formerly, barrels were coloured by exposing them to a degree of heat which produced an elegant blue tinge; but, as this effect arises from a degree of oxydation taking place upon the surface of the metal, the inside of the barrel always suffered by undergoing the same change. This, therefore, added to the painful sensation excited in the eye, by looking along a barrel so coloured, has caused the practice of bluing to be disused for some time past. Instead of it, barrels are now browned, as it is termed. To do this, the barrel is rubbed over with nitrous or sulphuric acid, diluted with water, and laid by until a coat of rust is formed upon it, more or less, according to the colour wanted; a little oil is then applied; and the surface being rubbed dry, is polished by means of a hard brush and bees-wax. When the barrels intended for a double-barrelled piece are dressed to their proper thickness, which is generally less than for single barrels, each of them is filed flat on the side where it is to join the other, so that they may fit close together. Two corresponding notches are then made at the muzzle and breach of each barrel; and into these are fitted two small pieces of iron, to hold them more strongly together. The barrels being united by tinning the parts where they touch, the ribs are fitted in, and made fast by the same means. These ribs are the triangular pieces of iron which are placed between the barrels, running on the upper and under sides their whole length, and serving to hold them more firmly together. The under rib is a late improvement, and is found more effectually to prevent the barrels from warping. When the barrels are thus joined, they are polished and coloured in the manner already described.

The twisted barrels are deservedly celebrated for their superior elegance and strength, but not justly so for the accuracy with which they throw either ball or shot. The iron employed in them is formed of stubs, which are old horse-shoe nails procured from country farriers, and from poor people who gain a subsistence by picking them up on the great roads leading to the metropolis. These are originally formed from the softest and toughest iron that can be had; and this is still further purified by the numerous heatings and hammerings it has undergone in being reduced from a bar into the size and form of nails. They cost about ten shillings the hundred weight, and twenty-eight pounds are required to make a single barrel of the ordinary size. A hoop of iron, about an inch broad, and six or seven inches in diameter, is placed perpendicularly; and the stubs, previously freed from dirt by washing, are neatly piled in it, with their heads outermost on each side, until the hoop is quite filled and wedged tight with them; the whole resembling a rough circular cake of iron. This is put into the fire until it has attained a white heat, when it is hammered, either by the strength of the arm, or by the force of machinery, until it coalesces, and becomes one solid mass of iron: the hoop is then removed, and the heatings and hammerings repeated, until the iron, being thus wrought and kneaded, is freed from every impurity, and rendered very tough and close in the grain: the workman then proceeds to draw it out into pieces of about twenty-four inches in length, half an inch or more in breadth, and half an inch in thickness. These pieces, however, are not all of the same thickness, some being more and others less than what we have mentioned, according to the proposed thickness of the barrel, and that part of it which the piece is intended to form. One of these pieces, being heated red-hot for five or six inches, is turned like a screw cork-screw, without any other tools than the anvil and hammer. The remaining portions are successively treated in the same manner, until the whole piece is turned into a spiral, forming a tube whose diameter corresponds with that of the intended barrel. Four of these are generally sufficient to form a barrel of the ordinary length, which is from thirty-two to thirty-eight inches; and the two which form the breech, or reinforced part, are considerably thicker than those which constitute the fore-part or muzzle of the barrel. The workman first welds one of these tubes to a part of an old barrel, which serves as a handle. He then proceeds to unite the turns of the spiral to each other, by heating the tube two or three inches at a time, to a bright white heat, and striking the end of it several times against the anvil in a horizontal direction, and with considerable force: this is termed jumping by the barrel; and the heats given for this purpose are called jumping heats. A mandril is then introduced into the cavity; and the heated portion is hammered lightly, to flatten the ridges, or burs, raised by the jumping at the place where the spirals are joined. As soon as one piece is jumped its whole length, another is welded to it, and treated in the same manner, until the four pieces are united; when the part of the old barrel, being no longer necessary, is cut off. The welding the turns of the spiral is performed exactly in the same manner as before described, and is repeated three times. The barrel is afterwards finished in the same way as a common one. Stub-iron is also wrought into plain barrels; which, as they require a great deal less labour, are only half the price of the twisted ones.

The proving of barrels differ in different countries. The Spanish proof is a very severe one; but, as it is made before the barrel is filed, it is not satisfactory. At the royal manufactories of St. Etienne and Charleville, in France, there were inspectors appointed to see that no barrels were sent out of these places, whether for the king's use or for public sale, without being proved.

proved. The first proof was made with a ball exactly fitting the caliber, and an ounce of powder. The second was made with the same sized ball and half an ounce of powder. The reason given for the second proof, is, that the first may have strained the barrel so much, though the injury be not visible, that it will not bear a second trial with a smaller charge; and it is said there really are some of these barrels which stand the first proof, and yet give way in the second. The usual proof of the Paris barrels is a double charge of powder and shot; that is, two or two and a half ounces of shot. The English Tower-proof, and that of the Whitechapel Company, incorporated by charter for proving of arms, are made with a ball of the proper caliber, and a charge of powder equal in weight to this ball: the proof is the same for every size and species of barrel, and not repeated.

It may be safely asserted, that a good barrel very seldom bursts, unless it be charged too highly, or in an improper manner. Whenever, for example, from the ball not being rammed home, a space is left between it and the powder, there is a great risk of the barrel bursting on being discharged. We say, a great risk, because, even under these circumstances, it frequently happens that the barrel does not burst. If the ball stops near to the powder, a very small windage is sufficient to prevent this accident; and it is very rare that the ball touches the barrel in every part of its circumference, unless it has been driven in by force with an iron ram-rod, in which case it moulds itself to the cavity, and blocks it up completely. Should this happen, the barrel, however strong it is, will burst, even when the space between the ball and the powder is but very inconsiderable; and the greater the space that intervenes, the more certainly will this event take place. Mr. Robins, when speaking of this matter, says, "A moderate charge of powder, when it has expanded itself through the vacant space, and reaches the ball, will, by the velocity each part has acquired, accumulate itself behind the ball, and will thereby be condensed prodigiously; whence, if the barrel be not of an extraordinary strength in that part, it must infallibly burst. The truth of his I have experienced in a very good Tower musquet, forged of very tough iron; for, charging it with twelve pennyweights of powder, and placing the ball (loosely) sixteen inches from the breech: on the firing of it, the part of the barrel just behind the bullet was swelled out to double its diameter, like a blown bladder, and two large pieces of two inches long were blown out of it." The same accident will often take place from the mouth of the piece being filled with earth or snow, as sometimes happens when we are leaping a ditch, with the muzzle of the piece pointed forwards; and, if in such cases the barrel do not burst, it is because these foreign bodies stop it up but very loosely. For the same reason, a barrel will certainly burst, if fired when the muzzle is thrust into water but a very little way below the surface; the resistance given to the passage of the inflamed powder through the mouth of the piece being in this case much greater than that afforded by the sides of the barrel. Except in the circumstances mentioned, or in case of an overcharge, it is very rare that a barrel bursts. Whenever it happens independently of these, it is from a defect in the work, and that either the barrel has been imperfectly welded, or that a deep flaw has taken place in some part of it: or, lastly, that through want of care in the boring or filing, it is left of unequal thickness in its sides. The last defect is the most common, especially in low-priced barrels; and, as pieces more frequently burst from it than from the other defects, it ought to be particularly guarded against. The elastic fluid which is set loose by the inflammation of the powder, and which endeavours to expand itself equally in every direction, being repelled by the stronger parts, acts with additional force against the weaker ones, and frequently bursts its way through them; which would not have been the case had the sides been of the same thickness and strength, and not afforded an unequal repercussion. The weakness of any part of the barrel, occasioned by the inequality of the caliber, will still more certainly be the cause of bursting than that produced by the filing; because the inflamed fluid being suddenly expanded at the wider part, must suffer a compression before it can pass onward, and the whole force is then excited against the weak place; for gunpowder acts in the radii of a circle, and exerts the same force on every part of the circumference of the circle. The conclusion to be drawn from all this is, that a thin and light barrel, which is perfectly upright, that is, of equal thickness in every part of its circumference, is much less liable to burst than one which is considerably thicker and heavier, but which, from being badly filed and bored, is left of unequal strength in its sides.

It has been found that the flight of balls, both from cannon and small arms, is liable to very considerable variations; and that the piece, notwithstanding it was firmly fixed, and fired with the same weight of powder, sometimes throws the ball to the right, sometimes to the left, sometimes above, and at other times below the mark. It has also been observed, that the degree of deflection increases in a much greater proportion than the distance of the object fired at: thus, at double the distance the deflection of the ball from the line on which the piece is pointed is considerably more than double, and, at treble the distance more than treble what it was in the first. Mr. Robins secured a musket-ball upon a block of wood, and firing it with a ball, at a board of a foot square, sixty yards distant, found that it missed the board only once in sixteen successive discharges; yet when fired with a smaller charge, at the distance of seven hundred and sixty yards, it sometimes threw the ball one hundred yards to the right, and, at other times, one hundred to the left of the line it was pointed in. The direction upwards and downwards also was found equally uncertain, the ball sometimes bending so much downwards as to fall two hundred yards short of its range at other times. Yet the nicest

nicest examination could not discover that the barrel had started in the least from the position in which it was first fixed. It is impossible to fit a ball so accurately to any plain piece, but that it will rub more against one side of the barrel than another, in its passage through it. Whatever side, therefore, it rubs against on its quitting the muzzle, it will acquire a whirling motion towards that side, and will be found to bend the line of its flight in the same direction, whether it be to the right or the left, upwards, downwards, or obliquely.

This deflection from a straight line arises from the resistance which the air gives to the flight of the bullet, it being greatest on that side where the whirling motion conspires with the progressive one, and least on that side where it is opposed to it: thus, if the ball, in its passage out, rubs against the left side of the barrel, it will whirl towards that side; and, as the right side of the ball will therefore turn up against the air during its flight, the resistance of the air will become greatest on the right side, and the ball be forced away to the left, which was the direction it whirled in. If the axis round which the ball whirls preserved its position during the whole of the flight, the deflection would be in the same direction from the one end of the track to the other. But, from accidents that are unavoidable, the axis of the whirl frequently changes its position several times during the flight; so that the ball, instead of bending its course uniformly in the same direction, often describes a track that is variously contorted. So great, however, is the tendency of the ball to deflect itself towards the side it rubs against, that although, when fired out of a barrel that is bent towards the left hand, it will be thrown from the piece in the direction of the bend, yet as the ball in this case will be forced to rub against the right side of the muzzle, and thus turn its left side up against the air, so it will be found to alter its course during the flight, and bend away towards the right-hand, so as to fall a considerable way to the right of the line in which the piece was pointed.

From what has been said, it will readily appear, that these variations will be more frequent and considerable when the ball runs very loose in the piece; or when, from any roughness on its surface, or on the inside of the barrel, a considerable degree of friction takes place between them. With a view to prevent friction, it has been proposed to grease the ball; but this will be of little service. All that can be done in a plain barrel, is, to have the balls cast very solid and true, and afterwards milled in the same manner as is now practised upon shot: the barrel also should be very smooth on the inside, and the ball fit it very accurately, so as to leave scarcely any windage. And yet, with the help of all these, it will still be very difficult to prevent it altogether; for gravity will constantly act, and friction on the under side will naturally be occasioned by the weight of the ball.

From considering the causes of this aberration in the flight of the bullets, it will be pretty evident, that the only means of correcting it is by preventing the ball from rubbing more against one side of the barrel than another in passing through it; and by giving to the bullet a motion, which will counteract every accidental one, and preserve its direction by making the resistance of the air upon its fore part continue the same in every part of the flight. The contrivance for this purpose is termed rifling, and consists in forming upon the inside of barrels a number of furrows, either in a straight or spiral direction; into these the ball is moulded, and any rolling motion along the sides of the barrel, in its passage out, thereby prevented. Barrels of this construction have been in use upon the Continent since the middle of the sixteenth century, but were little known, and still less employed in England, until within these fifty years.

The spiral rifled barrels, however, have entirely superceded the straight rifled ones, because, although the latter prevented the rolling motion of the ball that takes place in a plain barrel, yet they do not communicate any other motion, that could serve to correct the variations that may occur during the flight. The furrows, or channels, which are termed the rifles, vary in number according to the fancy of the workman, or that of the purchaser, but are never less than six, or more than twelve, in a common-sized piece. Their depth is equally subject to variation; but the breadth of the furrows and of the threads is generally the same. In some of the pieces, the spirals make a half-turn, in others, three-fourths, and in others, again, an entire revolution in the length of the barrel: an entire revolution, however, is the most common, though, from the great difference in the length of rifle-barrels, there should be some standard assigned for the obliquity of the spirals which would communicate a rotary motion to the ball, sufficient to correct any aberration in its flight; and this might be determined by comparing the effects of a number of pieces; that differed only in the obliquity of the rifles.

Barrels intended to be rifled are previously bored and smoothed within, in the manner already described: they are, however, forged as much thicker than plain barrels as the depth of the rifles; for, although the threads of the spiral add to the weight of the barrel, they do not increase its strength in the least, with regard to the force exerted upon it by the powder. These pieces are charged in various ways. In general, the ball, which is sometimes larger than the caliber before it was rifled, is driven down to the powder, by means of an iron rammer, struck with a mallet, whereby that zone of the ball which is in contact with the sides of the barrel becomes indented all round, and is moulded to the form of the rifles. When the piece is fired, the projections of the ball which fill the rifles, being obliged to follow the sweep of the spiral, the ball thereby acquires a rotary motion upon an axis that corresponds with the line of its direction; so that the side of the bullet which lay foremost in the barrel continues foremost during the whole of the flight. By this means

means the resistance of the air is opposed directly to the bullet's progress, and not exerted more against one part than another of that side which moves foremost; and accordingly the bullet preserves the line of its direction with very great steadiness.

It now remains to speak of the sights, which, although they do not constitute the essential part of a rifle, as they may be used with a plain bored barrel, yet as that is seldom done, and as they are always used with a rifle it will not be proper to omit mentioning them.

It may be strictly said, that no part of the path of the bullet when fired from a rifle or musket, is in a right line, as gravity acts upon the bullet the instant it quits the mouth of the piece, and, although at a small distance it is not very perceptible, yet it is considerably so at one hundred yards, and at two hundred yards the ball would probably strike the ground before it could reach the object aimed at. To remedy this inconvenience, it is found necessary to aim at exactly such a height above the object as the ball would have been depressed to by the power of gravity had it been aimed at it point blank, &c.; that if we suppose this depression to be a foot in a hundred yards, we must aim a foot above the object. But here another inconvenience arises, for if we aim above the object, by raising the muzzle of our piece, the object is excluded from our view, by the intervention of the barrel, so that we are prevented from measuring the distance with our eye, and, instead of one, are liable to aim two or three above it.

The second difficulty is removed by depressing the breach of the gun instead of elevating the muzzle, and the quantity of the depression is measured with great nicety by what are called the sights.

On the upper surface of the barrel, at right angles with its axis, is fixed a piece of flat thin iron, about six inches from the breech, and on the centre of its top a small square notch is filed. This is called the back sight. The front sight is nothing more than the small knob of iron, or brass, which is fixed on all fowling-pieces, about half an inch from the muzzle. When aim is taken, the eye is raised over the back sight till the front sight appears through the notch which is then brought upon the object.

With respect to the gun-lock, great care is taken in the manufacture of this article, and in the finishing it. This consists of divers parts, such as the cock, which is the part containing the flint: the priming-pan, to hold a small quantity of powder, which is connected with that in the barrel: the hammer, that which covers the priming, and against the upper part of which the flint strikes: the trigger, used to bring the flint and hammer in contact; and certain springs, as the main-spring, the rear-spring, &c., which are concealed in the stock, and which are adapted either to hold the cock on the half-cock, whole cock, or to extricate it at the moment of firing the piece.

Many attempts have been made to improve this part of the instrument, and to render it more safe in the hands either of inexperienced or careless persons, because, in common locks, it sometimes happens that the piece will go off when it is only on the half-cock, and when it ought to be perfectly secure from accident.

The "Society" in the Adelphi, for the encouragement of Arts, Manufactures, &c., have rewarded many persons for their ingenuity in this respect. We shall notice the improvements of Mr. Webb, and of Mr. Dodd; to the former they presented twenty guineas, as a mark of their approbation: to the latter, their honorary medal and ten guineas.

Mr. Webb's improvement may be thus described:—The lock is so contrived that when it is on full-cock, and the trigger pulled in the common manner, it returns to the half-cock only, unless at the same time that the trigger is pulled, the pressure of the thumb is applied on a spring placed upon the but or stock of the gun; in which case it gives fire in the usual way. The object of the invention is to guard against accidents which arise when fire-arms are left loaded, or the misfortunes which frequently happen from twigs of trees or bushes catching the trigger when sportsmen are passing through hedges, &c.

Mr. Dodd says his improved lock is so *perfectly* secure as to preclude the possibility of its firing when on the half-cock, either by accident, violence, or design. It possesses all the advantages of stop or bolt-cocks, without the inconveniences to which they are liable. Our readers shall hear his own account as taken from the twenty-second volume of the "Transactions" of the Society of Arts:—

"Though these improved locks are perfectly secure at half-cock, they will fire from whole-cock, with much more certainty than a lock having a hair-trigger, because less complex, and with equal fleetness.

"A most valuable improvement in this lock is, that pulling the trigger, when the piece is at half-cock, renders it more and more secure, the reverse of this being the case with common locks; for the more powerfully the trigger is pulled when they are at half-cock, the more insecure they become.

"Another truly essential improvement is, that this lock cannot possibly catch and stop, at the position of half-cock, when passing from the whole-cock, and miss fire; a serious misfortune, to which locks made on the common principle are so liable, that to prevent it, all the best of these use a peculiar piece of machinery called a fly, or détachant.

"The improved locks will be much less liable to be out of repair, as the bents are much deeper, and run through the solid metal direct towards the centre of the tumbler: unlike the usual bents, they are small, pointed, and the line of their depth near the circumference of the tumbler. Hence they are apt to be snapped off, or easily worn away, and fire from half-cock, as too frequently and fatally occurs.

"When these improved locks require cleaning, they are of so plain and simple a construction, as easily to be taken to pieces, and put together by any soldier or sportsman.

"To

"To put one of these improved locks to an old stock, it is merely necessary to make some trivial alterations in the excavation of the wood.

"The sportsman who has one of these improved locks to a fowling-piece, if the trigger should become entangled with a twig, may forcibly pull his piece away, assured, that in so doing, he increases his safety: but, if it be a common lock, he must turn back, and cautiously unloose, lest the piece explode.

"The improved locks possess four times the strength of common locks where the latter are weakest, and are of equal strength in all other parts.

"Among the many contrivances and complicated means to prevent pieces going off at half-cock, bolts have principally been used; but they are ill adapted to the purpose, exclusive of the additional expense; for few people, when alarmed, have the presence of mind first to unbolt the piece to render it fit for service, but they instantly attempt to cock. Disappointment adds to their agitation, and increases the confusion; and, ere they recollect their mistake, the lost moments, at such a juncture, may occasion the loss of their lives; especially from free-booters and rifle-men, who are always prepared before they attack, and seldom shew mercy to them from whom it appeared they had none to expect. But this lock is admirably devised for safety and service, as it merely need be cocked for use, and half-cocked for security; both which can be performed with expedition equal to that of any other lock that ever was made public.

"Common locks are subject to the most momentous failing of a false or delusive half-cock; for the nose of the sear rests on the point of the half-cock bent, which, as it causes no alteration in the external appearance, cannot be discovered, and its sad effects prevented. This very serious accident frequently occurs among recruits and unskilful gunners, from inattention to a very fine punctilio of military exercise; but it is utterly impossible that this should ever occur with the improved lock, by accident or even by design. The improved lock is constructed on more mechanical principles, and is much simpler, and more easy to manufacture, than any other lock. Hence, there will be no increase of expense in execution, but a considerable decrease to the locks of rifles, fowling-pieces, pistols, &c.

"Simplicity alone is deemed a valuable improvement; but, to this excellency, the improved lock unites a pleasing variety of new and useful superiorities, without sacrificing any advantage which the best of common locks at present possess.

"These improvements are equally applicable to all descriptions of fire-arms, civil as well as military."

We shall now give a description of a gun-lock, for which His Majesty's letters patent have been obtained by Mr. Manton, of Dorset-street.—In this the hammer acts downwards, and opens that side of the pan nearest the cock to admit the sparks of the prime. The hammer returning to its jointing, fills up the opening in the pan, and it is furnished with a strong steel pan, fastened by a stud in the back, and a small screw through the hammer. At the end of the hammer face, nearest the pan, is a small groove or notch, sunk in the hammer to carry off any wet that may come down upon it. The hammer is fixed to the plate by the same screw that fastens the hammer-spring on the inside. The hole in the shank of the hammer being screwed, it turns on the hammer-springs which comes through the plate about three-eighths of an inch. On the inside of the hammer-spring there is a projection one-fourth of an inch long, which comes through a square hole in the plate into a hole in the shank of the hammer, and forces it to return to its jointing with the pan, when the lock is brought to half-cock. The cock is flat on the inside, and is barely one-eighth of an inch thick. It passes between the plate and the hammer when it comes down. The jaws project outwards, to answer the hammer. A bulge is left on the breast of the cock to render the fitting of the squares of the tumbler more strong and perfect. When the lock is struck down, the flint comes in contact with the hammer-face, near the end, and forces it down sufficiently to admit the sparks into the pan. The inside of the pan is round, and the same size from end to end. About one-third is cut out to receive part of the hammer. The main-spring has a stud like others. The end of the stud size is bevelled to fit under the end of the nib, by which it is prevented from rising. The crane of the tumbler has a roller in the end, on which the main-spring acts. The bridle has a strong leg on the inside, with a round stud, which fits into the plate near the sear-nose, to prevent it from twisting when the tumbler comes in contact with the eye to stop the cock. The sear acts on the tumbler in the usual way, but the shank is nearly vertical instead of horizontal. The sear-spring acts on a shoulder, left on the outside of the sear for that purpose, and forces the sear-nose to the tumbler. The pan of this lock is primed from the touch-hole by the compression of the air in loading.

The following are described as the principal advantages derived from this lock;—1. The pan being solid with the plate at the top, protects the prime from wet. 2. The hammer opening downwards, and the flint acting in a direct line with the pan, the sparks communicate quicker to the prime. 3. The hammer returns to its jointing with the pan when the lock is brought to half-cock, without any additional trouble to the user. 4. The lowness and compactness of the lock altogether, render it much less difficult to protect from wet, and much less liable to accidents by catching, in cover-shooting, than locks of the present construction.

The lock, as we have already observed, is let into the gun-stock, which is uniformly manufactured from the wood of the walnut-tree, of which the gun-smith always keeps a large stock, and well seasoned. The gun-stocks are usually made by workmen at their own homes, because one man will fashion gun-stocks sufficient for the wants of several gun-smiths.

Before any of the pieces described are appropriated for service, it is necessary, as we have already observed, to

to have each undergo a particular trial of its soundness, which is called a proof, to be made by or before one authorized for the purpose, called the proof-master.

To make a proof of the piece a proper place is chosen, which is to be terminated by a mount of earth, very thick, to receive the bullets fired against it, that none of them may run through it. The piece is laid on the ground supported only in the middle by a block of wood. It is fired at three times; the first with powder of the weight of the bullet, and the two others with three quarters of the weight; after which a little more powder is put in to singe the piece; and, after this, water, which is impressed with a spunge, putting the finger on the touch-hole, to discover if there be any cracks; which done, they are examined with the cat, which is a piece of iron with three grasps, disposed in the form of a triangle, and of the caliber of the piece.

Having gone through the principal parts of the business to be treated on, we shall conclude the article with an account of the gun-flint, which is of great importance in the practice of gunnery, and the proper forming of which is a distinct trade in France, and is thus described:—

In France, the best flints are found in the neighbourhood of St. Aignan, in the department of the Loire et Cher, and in that of the Indre, and the departments that occupy the valleys of Siene et Marne; they occur as horizontal banks in fletz-limestone, particularly chalk, and also in marl. Among twenty of such beds or layers, situate one above the other, at the distance of about twenty feet, there is generally only one, very seldom two, that furnish good gun-flints. All those of a good quality are coated with a white earthy rind. On the banks of the Cher, the flints are excavated by means of shafts of from forty to fifty feet in depth, from whence levels or horizontal galleries are carried into the only good stratum which is known in that district; but on the banks of the Seine, in the hillocks of Rocheguyon, where the cliffs of chalk present broken precipices, one of these beds, which contain the best sort, is at about six fathoms' distance from the upper surface of the great mass of chalk.

The characters by which the good flints are distinguished from those less fit for being manufactured, are the following:—Their surface is rather convex, approaching to globular; those that are amorphous, or of a very irregular form, such as knobbed, branched, &c., are generally full of imperfections. Good flint nodules seldom exceed the weight of twenty pounds; nor are those that weigh less than one or two pounds considered as being of a good quality. Internally, they should appear unctuous and rather shining, with a grain too fine to be perceptible to the eye. The colour may vary from honey yellow to blackish brown, but the tint should be uniform in the same nodule. Their transparency should be sufficient to admit letters to be distinguished through a piece of stone of a quarter of a line thick, laid close upon the paper. Their fracture should be perfectly smooth and equal throughout, and the fragment slightly conchoidal. The last of these properties is most essential, since on it depends the facility with which the nodule is divided into gun-flints. All flints that prove deficient in any one of the above characters, either naturally or by a long exposure to the air, are called *intractable*, and rejected by the workmen.

The tools made use of by the makers of gun-flints are four in number.—1. A hammer, or mace of iron, with a square head, the weight of which does not exceed two pounds, with a handle of seven or eight inches long. This tool is not made of steel, for an excess of hardness would render the strokes too hard or dry, and would shatter the nodules irregularly, instead of breaking them by a clear fracture.

2. A hammer with two points. This is made of good steel, well hardened; its weight does not exceed sixteen ounces, it need not weigh more than ten ounces. Its handle is seven inches long, passing through it in such a manner that the points of the hammer are nearer the hand of the workman than the centre of gravity of the mass. The form and size of the hammers of different workmen vary a little; but this disposition of the points is common to them all, and is of consequence to the force and certainty of the blow.

3. The disk hammer, or roulette, a small tool which represents a solid wheel, or segment of a cylinder, two inches and four lines in diameter; its weight does not exceed four ounces. It is made of steel not hardened, and is fixed on a handle six inches in length, which passes through a square hole in the centre.

4. A chisel tapering and levelled at both extremities, seven or eight inches long, made of steel not hardened; this is set on a block of wood, which, at the same time serves as a bench for the workmen.

To these four tools we may add a file, for the purpose of restoring the chisel from time to time.

After having selected a good mass of flint the following operations are performed by the workmen:—

1. *To break the Block.*—The workman being seated on the ground, places the nodule of flint on his left thigh, and applies slight strokes with the square hammer, to divide it into smaller pieces of about a pound and a half each, with broad surfaces, and almost even fracture. the strokes should be moderate, lest the mass crack and split in the wrong direction.

2. *To cleave and chip the Flint.*—The principal operation is to split the flint well, or to chip off the scales of the length, thickness, and shape adapted to be afterwards fashioned into gun-flints. In this part the greatest degree of address and certainty of manipulation are required. The fracture of the flint is not confined to any particular direction, it may be clipped in all parts with equal facility.

The workman holds the piece of flint in his left hand not supported, and strikes with the pointed hammer on the edges of the great planes produced by the first breaking, by which means the white coating of the flint is removed in the form of small scales, and the mass of the flint itself laid bare; after which he continues

tinues to chip off similar scaly portions from the pure mass of the flint. These scaly portions are nearly one inch and a half wide, two inches and a half long, and their thickness in the middle is of about two lines. They are slightly convex below, and consequently leave in the part of the flint from which they were separated a space slightly concave, longitudinally bordered by two rather projecting straight lines or ridges. These ridges produced by the separation of the first scales, must naturally constitute nearly the middle of the subsequent pieces, and such scales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the fractures required, or until the piece is reduced too much to receive the small blows by which the flint is divided.

3. *To fashion the Gun-flint.*—Five different parts may be distinguished in a gun-flint. 1. The sloping facet, or bevel part, which is impelled against the hammer of the lock of the gun. Its width should be from two to three-twelfths of an inch: if it were broader it would be too liable to break; and if more obtuse, the scintillation would be less brisk. 2dly. The sides, or lateral edges, which are always rather irregular. 3dly. The back, or the part opposite the tapering edge: this is the thickest part of the flint. 4thly. The under surface, which is uninterrupted and rather convex. And, 5thly. The upper facet between the tapering edge and the back, which receives the upper claw of the cock; it is slightly concave.

In order to fashion the flint, those scales are selected that have at least one of the above-mentioned longitudinal ridges: the workman fixes on one of the two tapering borders to form the striking edge; after which the two sides of the stone that are to form the lateral edges, as well as the part which is to form the back, are successively placed on the edge of the chisel in such a manner that the convex surface of the flint, which rests on the fore-finger of his left hand, is turned towards that tool. He then, with the roulette, applies some slight strokes to the flint just opposite the edge of the chisel underneath; by which means the flint breaks exactly along the edge of the chisel.

4. The finishing operation is the trimming, or the process of giving the flint a smooth and equal edge; this is done by turning the stone and placing the edge of its tapering end on the chisel, in which situation it is completed by five or six slight strokes with the solid wheel.

The whole operation of making a gun-flint is performed in less than one minute. A good workman is able to manufacture a thousand good chips or scales a day, if the flint nodules be of a good quality; and in the same manner he can fashion 500 gun-flints in a day; so that in the space of three days he is able to cleave and finish a thousand gun-flints without further assistance. This work leaves a great quantity of refuse, for scarcely more than half of the scales are good, and nearly half the mass in the best flints is incapable of being chipped out, so that it seldom happens that the largest nodules will furnish more than fifty gun-flints. Such scales as have a crust, or are too thick to be made into gun-flints, are used for the more common purpose of striking a light. The gun-flints are sorted out according to their perfection, and the use to which they are to be applied. They are classed into extra and common flints: flints for pistols, muskets, and fowling-pieces. This account of gun-flints is taken from a paper published by Citizen Dolomieu in the third volume of the "Memoires de l'Institute Nationale," which was translated and partly abridged in the second number of Nicholson's Journal, octavo edition. It is said, that a single workman, named Stephen Buffet, who emigrated from the commune of Meunes to the banks of the Seine, where he has carried on this art for about thirty years by himself, was the person from whom Dolomieu obtained the present instructions. There are a few other places in France where this art is practised, but in none to the extent of the places before-mentioned. The author has not met with this manufactory in any other countries, except in the territory of Nicenza, and one of the cantons of Sicily. He remarks that it may be carried on elsewhere, though probably overlooked by travellers, on account of its apparent insignificance. I believe it is practised at Purfleet, in the county of Kent, and in various other parts of England.

HAT-MAKING.

SOME kind of covering for the head, either for defence or ornament, appears to have been generally worn in all ages and countries where the inhabitants have made any progress in the arts of civilized life. It has, indeed, been stated on the authority of Herodotus, that the Egyptians were accustomed to appear bare-headed; but this assertion must be considered as subject to limitation, probably comprising only some of the poorer classes of the community, as from other documents it appears they were no strangers to this article of dress, and it is well known that a crown was the signature of royal authority. The form, substance, and colour of head-dresses have been exceedingly various, according to the different circumstances or humour of the wearers. The Persians wore turbans, and other nations inhabiting the Indian Peninsula, wore a kind of covering for the head which, like the thick-laid thatch of a lowly cottage, seemed calculated to divest the whole building of all proportion. The imperial turban is said to have been composed of almost a whole bale of muslin, twisted and formed nearly in an oval shape, surmounted with a woollen cap, encircled with a radiated crown: the ministerial turban was smaller in its dimensions, but of superior altitude. The turban of the chief magi, on account of his superior eminence, was higher than those of the monarch and minister united; and, by a regular gradation preserved among those of the inferior magi, the most ignorant could *ascertain* their situation and dignity. The Jews wore a variety similar to those of the nations with whom they were connected. From the Persians they borrowed those large turbans which adorned their elders, doctors, and scribes. The mitre of the priests was their own. Several of their tribes adopted the caps which the Romans were accustomed to give their slaves on their manumission;* and which is said to have borne a great resemblance to some worn by the polished Jews to this day. The ancient helmets were a substitute for hats, made of steel, brass, and sometimes more costly metals. In our own country, Stowe informs us, that "The English used to ride and go winter and summer in knit caps, cloth hoods, and the best sort in silk thrummed hats."

Head dresses, from their variety, simplicity, and mutability, had hitherto been an object of little regard in a manufacturing or commercial point of view. The introduction of felt hats has occasioned a uniformity and extent to this article of dress unknown in former ages; and has proved of considerable importance to the manufacturer and the tradesman. Curiosity is naturally excited to become acquainted with the particulars respecting their invention, and the subsequent stages of improvement in the manufacture; but the operation of individual interest, so generally connected with the useful arts, seems to have concealed the whole in obscurity, and *little information on the subject* can now be obtained.

The hatters have a tradition among them, that while St. Clement, the fourth bishop of Rome, was fleeing from his persecutors, his feet became blistered, and, to afford him relief, he was induced to put wool between his sandals and the soles of his feet. On continuing his journey, the wool, by the perspiration, motion, and pressure of the feet, assumed a uniformly compact substance, which has since been denominated *felt*. When he afterwards settled at Rome, it is said he improved the discovery; and from this circumstance has been dated the origin of felting. It affords a confirmation to the truth of the account that the hatters in Ireland, and in several other catholic countries, still hold a festival on St. Clement's day. It does not appear, however, that St. Clement so far improved the occurrence, as to have hats formed of this substance: these are said to have been invented at Paris, by a Swiss, about the commencement of the 15th century. They were not generally known till Charles the Seventh made his triumphant entry into Rouen in the year 1449, when, from F. Daniel's account of that entry, it appears he astonished the whole city by appearing in a hat lined with red silk, and surmounted by a plume of feathers; from this entry their general use is dated.

When the clergy first adopted this part of dress, it was considered as an unwarrantable indulgence: councils were held, and regulations published, forbidding any priest or religious person to appear abroad so covered; and enjoining them to keep to the use of chaperons or hoods, made of black cloth, with decent cornets: if they were poor, they were, at least, to have cornets fastened to their hats, upon penalty of suspension and excommunication. And, by the statute of 13 Elizabeth, every person above the age of seven years, and under a certain degree, was obliged on Sundays and holidays to wear a woollen cap, made in England, and finished by some of the fraternity of cappers, under the penalty of three shillings and four-pence for every day's neglect. This statute was repealed the 39th Eliz.

How

* The ancient Romans gave a *pileus* or cap to their slaves in the ceremony of making them free: whence the proverb *vocare servus ad pileum*. Hence also on medals the cap is the symbol of Liberty, who is represented either as bearing it on the top of a spear or holding it by the point in her right hand.

How far the manufacture of hats was practised on the Continent before they were made in England, we are not able to say: from Stow's Chronicle we learn, that about the beginning of Henry the Eighth, began the making of Spanish felts in England, by Spaniards and Dutchmen: from hence it appears, that before this time, in Spain and Holland they were no strangers to the art. In the second year of James the First, the felt-makers of London obtained a corporation, and hired a hall near Christ-church, the king granting them various privileges and liberties for their support. Hats are at present made in different countries on the Continent, and in America; but they have not been made in any considerable quantities, or attended to as an article of commerce, except in France and our own country. From France they were exported, in large quantities, to England, Spain, Italy, and Germany: the quantity now made there is inconsiderable: England has, in its turn, become the grand mart for the manufacture; and from hence the article is exported to different parts of the Continent, America, and various other parts of the globe. To encourage the manufacture of hats our own laws prohibit their importation.

Felt hat-making consists in a method of working up wool or hair into a species of cloth, independently of either spinning or weaving; and giving it a convenient form, with a degree of stiffening sufficient to preserve its figure, and to answer the purposes of wearing. The mechanism of felting is curious and interesting: it depends on the conformation of all animal hairs and wool, which disposes them to unite with each other in such a manner as to produce a firm and compact substance.

On examining hairs, or filaments of wool, with the naked eye, or even by a low magnifying power of the microscope, they appear perfectly smooth and even. Their surface, notwithstanding, is by no means smooth; but composed of lamellæ, covering each other from the root to the point, in a manner resembling that by which the scales of a fish cover the animal from the head downwards. This disposition of the lamellæ on the surface of hairs is discoverable by holding a hair with one hand, and drawing it between two fingers of the other, in the different directions from the root to the point, and from the point to the root. In the former case no sensible friction takes place, nor is any roughness discoverable: in the latter we discover a very sensible resistance, which is most readily discerned by moistening the fingers. The following experiment is still more decisive. By holding a hair between the fore-finger and thumb, and rubbing it in the longitudinal direction, a progressive motion takes place, and this motion is invariably towards the root, or with the root of the hair foremost. For example: if the hair be held in a perpendicular direction with the root upwards, by rubbing the finger and thumb together, it will be found to assume a motion by which the extremity of the hair, pointing upwards, will rise still higher; but if the hair is turned, so that the extremity farthest from the root be placed upwards, its rising motion is discontinued, and it immediately recedes downwards. This is analogous to what happens when children, by way of sport, introduce an ear of rye or barley between the wrist and the shirt, the points of the beards of which are directed outwards. By the various motions of the arm, this ear, sometimes catching against the shirt, sometimes against the skin, takes a progressive motion backwards, and soon gets up to the arm-pit. It is very clear, that this effect is produced by the beards of the ear, and, indeed, chiefly by the asperities upon those beards, which being all directed towards the point do not permit the ear to move in any other direction than towards that part to which it was united to the stalk.

This conformation of the surface of hairs and wool, which appear to be composed of hard lamellæ or asperites, placed over each other likes tiles from the root to the point, lays the foundation of felting. In a layer of the material, by the operation it undergoes, the hairs are brought into close contact by their progressive and uniform motion towards the root; and meeting in various directions they become twisted together, the lamillæ of the different hairs fixing themselves to others directed in a contrary way, at the same time, preserving the whole in a close and compact substance.

The materials in general use are, lambs' wool, rabbits and hares' fur, beaver, seal wool, monkey stuff, or neuter wool, camels' hair, goats' hair or estridge, silk, and cotton. Moles' fur, and otter wool, are likewise sometimes made use of. The foreign lambs' wool generally used is the Italian, Spanish, and Peruvian, or vicuna wool, commonly known among hatters by the name of red wool. Our native wools are of various qualities: those in most esteem are the Herefordshire, or Ross wool, Southdown, Wye-side, Wiltshire, Somerset, and Hampshire. There is likewise wool sheared from Spanish lambs bred in England, known by the name of merino. Cod-wool is the wool plucked from lambs who die in the birth; long cod-wool is that plucked from lambs that die in early life. The best fur is from the backs of the different animals, and it decreases in value as it approaches the belly. Rabbits' fur, including the backs, and the best part of the sides mixed together, is known in the market by the name of *best stuff*; the fur from the bellies and worst part of the sides, seconds; that from odd bits of skins, &c., clippings; and the fur taken from rabbit-skins, when they are out of season, is denominated quarter-wool. The fur from unseasoned hare-skins is called stage hare-wool: with this is mixed also the inferior fur from seasoned skins. The best fur from the beaver is ruffing; the next in value, cheek-napping; and the inferior sorts are black-wooms, brown-wooms, white-wooms, brown-stage, and white-stage. Old-coat is taken from the beaver-skins that have been worn by the savages; but little of this article is now imported.

The wools are washed and carded, and when very long, cut to a moderate length with a chopping-knife, or hatchet, on a wooden block. White Russia best-

stuff

stuff and hares' wool, and the most inferior stuffs, as clippings, tail-wool, &c., are improved by the operation of carrotting. For this purpose, a layer of the stuff is placed in a box, or any suitable vessel, not of metal, and sprinkled over with a mixture of about one part nitrous, or nitrous and sulphuric acid, and six parts water, by means of a brush. A second layer is then placed in the vessel, which is again sprinkled with the acid mixture; this is repeated till it is full. To prevent the liquor running down into the bottom of the vessel, without equally wetting all the stuff, its position is frequently changed in the course of the day: it is then kept in the digesting heat of a stove all night. By this treatment the stuffs acquire a ruddy or reddish yellow colour, like the inner part of a carrot, from which it derives its name.

In felting any of these materials together, the first object of the workman is to obtain the most complete separation of the fibres, and to dispose a layer of them in every possible direction with regard to each other; this is effected by means of bowing. For this purpose, a platform of wood, about four feet wide, is erected against the wall of a convenient shop, and divided by side partitions about the same width from each other, into distinct portions, for the convenience of different workmen, called hurdles, each of which is enlightened by a small window. To each hurdle is suspended a bow, by means of a small cord fixed to the ceiling, or any other convenient place, consisting of a pole about seven feet long, generally made of deal-wood, to which are fixed two bridges of hard wood, the upper one nearest the window, called the cock, and, the lower one, the breech. To the upper part of the pole, above the cock, is fastened a cat-gut line, or bow-string, of considerable length, and twisted round the pole, leaving only sufficient to bring over the cock and breech, and to fasten to the lower part of the pole: thus, when the string breaks, it is partly untwisted from the upper end of the bow, and the necessity of a new one is prevented. To preserve the wood from wearing by the action of the bow-string, a strip of horse-skin, or vellum, is fastened to the edge of each bridge; and near the cord, by which the bow is suspended, is fastened a small strap to place the hand in, which enables the workman to hold it with firmness. The bow-pin is a small stick with a knob at each end for plucking the bow-string.

As the process of making is a little different in different kinds of hats, we shall first describe the manufacture of wool hats, or cordies. A quantity of carded wool, of one or more sorts, sufficient for one hat, generally about seven or eight ounces, is laid on the hurdle, towards the left. The workman then holding the bow horizontally in his left hand, under the strap, and the bow-pin in his right, placing the bow-string near the right-hand edge of the material, gives it a pluck with the pin. The string immediately flies back nearer to the pole than its situation was when at rest, strikes into the wool, and, instantaneously returning to its original position, scatters a part before it to a distance proportioned to the force with which it was pulled. By repeated strokes the whole is thus worked, observing, after each stroke to raise the string, by giving the bow a turn with the left hand. This breaking over, as it is termed, is repeated several times, more or less, in proportion to the difficulty with which the hairs are disunited: when all the fibres are completely separated, the material is again placed towards the left-hand side of the hurdle, and the workman proceeds, with more order than before, to scatter the wool to the right-hand, so as to form a thin regular layer; which he effects by duly proportioning the force of his strokes, and the position of the bow. When about one-third part is thus bowed, it is formed by the hands into an oval figure, ending in acute angles at the extremities. This portion of the material, thus formed, is called a batt.

The batt is hardened by a slight pressure with the hands for a short time, so as to connect it together sufficiently to bear careful handling. Another batt is then formed of the same dimensions; and with the remaining third part, two smaller batts are formed, which are separately united to the primary ones by a little pressure. This gives each of them a more uniform consistence than would be obtained by forming single batts only. It was formerly common to form six batts for each hat, but few are now willing to devote sufficient for the purpose. It is necessary to remark, that the batts are bowed thicker in that part which is designed to form the band of the intended hat; and to give them a finish, the edges are torn round even by the right-hand, while the pressure of the left prevents their being torn in too far.

It now remains to connect the parts together in some convenient form, and to proceed in the operation of felting. For this purpose, a wet cloth is folded so as to form a triangle, and laid on one of the batts. The extremities of the batts, with a small portion of the upper part is then folded over the cloth, and the edges meeting over each other form a conical cap. This cap is laid on the second batt with the joining downwards, which being also folded up in the same manner, their places of junction will be diametrically opposite each other. This is laid on a second wet cloth, which is closely folded over the whole, so as to preserve the triangular figure; it is then ready for basoning. The bason is a circular piece of iron, exactly the same as those commonly used in Wales for baking over the fire, called backstones. This is laid over a hole in a plank, underneath which is a small grating fitted to the plank for this purpose. The prepared cap is then laid on the warm iron, and the process of felting carried on by folding, pressing, and sprinkling it continually with water. The corners being folded over a little, the base is first turned up towards the tip; and in this state it is worked a short time by pressing with the hands, moving them backwards and forwards, and shifting them about in various directions. Each side is then

then folded over towards the other alternately, the tip part towards the base; and, in general, it may be folded in any or every direction, repeating the pressure and working of the wool, and sprinkling it successively after every fold. By this pressure and working the wool in various directions, the points of contact is multiplied; and the agitation given to each hair causing a progressive motion towards the root, and a coalition with each other, it soon acquires some degree of firmness and contracts in its dimensions.

On taking off the cloth, and opening the hood or cap, it will be found that the edges, or original folds, will not have that even and uniform appearance with the rest of the surface, but small ridges will be formed by a small part of the sides felting together at the outward edges, which will be considerable if care has not been taken in the first place to fold the batt closely over the in-layer. It is found necessary, therefore, to alter the position of the original edges, by turning round the cap, to extend them a little with the finger so as to produce a uniform surface, and with the hood in this position to continue the basoning as before. It is afterwards turned inside outwards, and the same operation continued. The workman afterwards opens the hood, holds it up to the light and looks through it from the inside to discover any parts that may be unusually thin; and, on any of these parts, which are deficient, a little wool is added from that which was torn off the edges of the batt; and by working that particular part on the bason it is made to unite. When this is done, the process of basoning is completed, which generally takes from about twenty minutes to half an hour.

The hood now consists of a soft spungy kind of stuff, and its texture is loose and imperfect. To produce a more intimate cohesion of the hairs with each other, and obtain the requisite degree of consistence, it must undergo a kind of fulling, and a more effectual mechanical operation. For this purpose, the hats are first boiled in an iron boiler, in a mixture of about one part urine to six parts soft water, from six to eight hours. To prevent their touching the boiler, they are enclosed in a cloth; a basket, or, more generally, a lining of straw is placed round the sides, and at the bottom of the boiler. The felting is completed by working or planking at a water bath. For the convenience of any particular number of workmen, an apparatus, called a battery, is generally made use of for this part of the process, consisting of a proportionate number of wooden planks, joined together in the form of the frustrum of a pyramid, supported by stone or brick work, and meeting at the bottom in a kettle, under which is a fire-place. The number of planks is most commonly from five to seven; and according to the number made use of, it is called a five, six, or seven-room battery, &c. Each plank is from two to three feet broad at the upper edge, and about two feet deep. The kettle is generally of cast iron or lead, and kept full of soft water, as nearly boiling as the nature of the operation will admit. To facilitate the felting, it is found necessary to add some softening material to the bath: for this purpose, some spermaceti, a marrow-bone, or shreds of wash-leather, have been thrown in; but oatmeal is at present almost universally used: about a table-spoonful is thrown into the kettle, and occasionally repeated as fresh water is added, or as it may be found necessary. The more greasy substances will answer for the purpose of planking, but it prevents the hats from taking a good dye: leather-shreds answer very well, but are not always so easy of access as oatmeal.

The operation commences by dipping the article in the bath, and gently rolling it in various directions, observing a degree of regularity, as in basoning, or its receiving more work in some parts than others, will soon give it an irregular and shapeless appearance. It is necessary to be careful at first to turn the hood inside outwards, and to shift the position of its sides frequently to prevent their felting together, of which, in the subsequent stages of the process there will be no danger. By working a short time in this way, the article will be found to have acquired a considerably firmer texture, and to have contracted very rapidly in its dimensions. The workman then applies leathern gloves, or flat pieces of stout leather, to the palms of his hands, to secure them in some degree from the heat of the water, and continues to dip it much oftener, and to roll it much harder than before, as it requires more labour in this degree of felting, to obtain the requisite firmness and consistence. In the first gentle rolling, an impulse, nearly equal, was given to the hairs in every direction, and hence it so readily contracted in its dimensions at the same time that it acquired a degree of firmness in substance. In rolling it harder, the pressure is more particularly on the flat surface of the felt, and this acquires a more compact texture, without an equal contraction in the size. It is however necessary to prevent any contraction in size when it is sufficiently shrunk, and yet worked to any degree of consistency. For this purpose, a small roller of wood, called a walking-pin, is made use of: over this the edges of the felt are turned, and the whole is rolled in various directions with the walking-pin enclosed by the surrounding felt; at the same time, continuing to dip it often in the bath. This completes the working at plank; and on the labour thus given its service in wearing will principally depend.

The intended hat, after the preceding operation, still possesses the conical figure first given it, consisting of a soft flexible felt, capable, with a moderate degree of force of being extended in every direction. The next thing to be done is to give it the required form. For this purpose, the edge of the hood is turned up about one and a half or two inches: the point is then indented with the fingers, and the hood turned over, so as to produce a second inner fold about the same depth. From three to five folds are thus formed, and the whole has the appearance af a flat piece, consisting of a number of concentric circles, or wave-like undulations. This

This is laid upon the plank, and the workman, keeping it wet with clean warm water, extends the central point with the fingers of his right hand, at the same time pressing it down with his left, and turning it round on the plank, till a flat portion is formed equal to the intended crown of the hat. The flat part is then placed in a block, and the remainder pulled down with the hands round its sides and a string tied tight round; it is forced down to the bottom of the block with a wooden or copper stamper, which forms the band. The brim will now have a curling inclination towards the crown, but is soon flattened by wetting and extending the edges. The water is afterwards pressed out of the hat with the blunt edge of the stamper, and the nap is raised by carding it in any direction with a small wired instrument called a raising card. The hat is then taken off the block and placed in a stove to dry, when it is ready for the subsequent operations of dyeing, stiffening, and finishing. These instructions for blocking refer particularly to the common round hat now generally worn; but from the nature of the felt it will be seen that any form may easily be given it by the skill of the workman, with a corresponding block.

This account we have given comprises the general principles of hat-making, and is the foundation of every variety in the art. These common wool hats, or plain cordies are of one uniform contexture throughout; but ingenuity has contrived a method of making the most of the materials employed, by placing the best side outwards. This is done by laying on the body of the hat when partly felted a finer and more valuable material, in the same direction it has when on the back of the animal. For the purpose of covering wool hats, the articles made use of are cod-wool and camel's hair: the former of which, after washing and carding, is boiled about an hour and a half in one part urine to about twelve or fourteen parts of water. The hats covered in this manner are bowed, basoned, and boiled in the usual manner, the common materials being used only in less quantity, proportioned to the addition intended to be made. A thin layer of the prepared cod-wool, with or without the addition of hair, is then bowed for each side of the triangular hood, so as just to meet at the edges; and another piece to go all round on the inside to the depth of the intended brim. The pieces are laid on the principal stuff or body of the hat, and worked on by basoning in the manner already described: the hairs assuming a motion towards the root, uniformly fix themselves in that direction, leaving the extremities outward which constitute the required nap. After this addition of the nap, the planking takes place as before.

For obtaining a variety of cordies of different value, they are partially as well as wholly covered with different proportions of napping, and on bodies of wool more or less valuable. Next to the plain hats succeed the tips: these have only a nap sufficient to cover the crown and reach a short way down the sides. To save the trouble of basoning the nap on these kind of hats, it is only laid on with the hands, the hood turned so that the nap may be inside, and a layer of some proper flexible substance, commonly long horse-hair, placed between the sides to prevent its uniting: in this manner it is taken immediately to the plank. The second class is tips and naps; these, as well as a cod-wool tip, have a nap of the same on the underside of the brim. And, lastly, succeeds the covers. A good cover takes about two ounces of cod-wool, and a hair cover about half an ounce of hair in addition to the cod-wool; these are commonly bowed together; and the former is scarcely ever used for a nap without the addition of the latter.

Stuff hats appear to have been originally made throughout of beaver; the instructions given in the old accounts of hat-making is, to mix three parts of old coat with two parts of castor; but hats made in this way would be much higher in price than any now in general use. The beaver at present is scarce ever used except in the outward nap, and the body of the hat is composed of various inferior stuffs in any proportion; commonly with the addition of a little Spanish or of vicuna wool, and sometimes a small quantity of silk is added. A patent was granted Mr. James Burn, of Alnwick, Northumberland, for making superfine hats, which, contrary to general modern practice, appear to have been of one uniform consistence. The composition consists of three ounces and a half of moles' fur, two ounces and a half of beaver, and a quarter of an ounce of Aleppo wool; "and in order to subdue the obstinate nature of the mole fur," says Mr. Burn, "so that it may incorporate with other furs usually made into hats, I use a little aqua regia; but as that process destroys the elastic quality of the fur, I correct it by a little sweet or Florence oil, which sheathes the pungent points of the aqua regia."

M. Monge says, "that the hairs of the beaver, the rabbit, the hare, &c., being naturally straight, cannot alone be employed in felting till they have undergone a preliminary operation, which consists in rubbing or combining them before they are taken off the skin, with a brush dipped in a solution of mercury in aquafortis (nitrous acid). This liquor, acting only on one side of the substance of the hairs, changes their direction from a right line, and gives them that disposition to felting which wool naturally possesses." However plausible this may appear in theory, experience teaches it is unnecessary in practice, as no difficulty is found in felting stuffs without any mixture of wool; and though the solution might have been made use of in France, we cannot learn that it has been employed in any manufactory in England.

Stuffs possess, in general, a greater tendency to felting than wool, and in consequence some small difference is observed in the manufacture. As the fibres are more easily separable, a slighter bow with a finer bow-string is used than that made use of in wool. When the stuffs are bowed in the usual way, the batts are formed and gently pressed down with a piece of osier work, called a gathering basket, consisting of open

open straight bars only interwove sufficiently to connect it together, and preserve it in form; it is from eighteen to twenty inches square. This is constantly kept on the hurdle, for the purpose of shifting the stuff as well as for forming the batts. Sometimes one or two of these baskets are placed under the stuff to separate any impurities that may pass through. To obtain this end more effectually, in the metropolis and several places in the North of England, a fine moveable wire frame is placed on the hurdle on which the stuff is broken over, which is again removed, and the impurities swept off the hurdle for forming the batts.

These have their first degree of compactness given them by laying on a hardening skin of smooth leather, or sailcloth; and gently pressing with the hands which are at the same time slightly moved backwards and forwards to cause the entangling of the fibres. The cap is formed in the same manner as wool hats, only the in-layer for stuff is a piece of wetted paper instead of cloth. When folded up in a wet cloth it is worked on the hurdle in the same manner that other hats are on the bason, but without any heat except what is imparted by the hands or any subsequent sprinkling. After being thus basoned without any boiling, they are immediately taken to the battery to undergo the operation of planking. In consequence of the superior smoothness of furs over wool, any softening material in the kettle is unnecessary: but it is indispensable that some substitute be made use of which will have an effect equivalent to boiling in the former case. For this purpose, wine lees was formerly in general use, but this has given place to sulphuric acid, which from the smallness of the quantity made use of is cheaper, and more easily obtained. About a wine-glassful of the acid is added to the kettle of water; in pouring in which great care is necessary to prevent its sprinkling over the operator: it is afterwards added in small quantities as it is found necessary. Into this bath the hat is first dipped, and then suffered to lie on the plank till cold again. This is called soaking, which is unnecessary in hats that are previously boiled.

In America, we, understand, it is the practice to boil stuff hats as well as cordies. It appears that the acid in carrotting, boiling, and working at the plank must act as a chemical agent on the substance of the hairs, but in what way it does not appear that experiments have been made with a view to ascertain: practical hatters seldom give themselves the trouble to think on the subject. M. Chaussier conjectures that it may produce, either by softening or swelling the hairs, a certain alteration which is necessary to bring about the cohesion of the different fibres. It is said, "that acid of any kind, by taking out the greasy substances on each pile of hair allows the roughness on the surface of each to operate with their full effect, and thus facilitates the mechanical action of felting." The action of felting being promoted, however, by greasy substances, renders this last solution a little doubtful. Perhaps some kind of mucilaginous substance may be on the surface of the hairs, as conjectured by Mr. Nicholson, which is disengaged by the action of the acid.

In the course of planking, imperfections are discovered; knots and other hard substances which occasionally remain in the stuff when imperfectly bowed, are picked out with a bodkin, and the stuff which was torn off the edges of the batts is added to such parts as are found deficient. This is laid on the imperfect parts, sprinkled over with a brush called a stopping-brush, and patted down with it while wet: by this means it incorporates with the rest. In the same manner the nap is laid on, which is generally added towards the conclusion; and it is gently rolled in a horse-hair cloth till the nap is slightly attached. The nap will be longer or shorter, as it receives more or less work after it is added, which causes it to enter a proportionable depth into the body of the hat.

Plated hats are an article of more modern date: they are said to have been invented in the north of England sometime within the last fifty years; and Lancashire and Cheshire is at present the principal seat of their manufacture. These are a middle class between cordies and stuffs, designed as a substitute for the latter at a more reasonable expense: to effect this purpose the different kinds of stuff are plated on wool bodies. But in consequence of the looser texture and thicker substance of this kind of felt, a nap of much finer materials could not be laid on in the usual manner so as to appear to advantage: it is found requisite therefore to have recourse to another expedient. The wool body, after it is boiled in about one part urine to three parts water, and has been worked sufficiently to complete the felting, is laid over a hair-cloth on the plank: the nap is then laid on the surface, sprinkled with a brush, and patted down. A layer of old stuff, or stuff which has its properties of felting destroyed, and carded cotton, or either of these separately, is bowed and laid on in the same manner, commonly mixed with a small portion of napping; and sometimes another layer is added. It is then slightly rolled a short time in the hair-cloth; but as the nap, by the process of rolling, would soon be lost by penetrating too deeply into the felt, it is discontinued, and the nap is fixed on by the operation of shaking and patting with the stopping-brush. The workman dips the article in the bath, and holding it by one of its edges between the forefinger and thumb of each hand, strikes it down on the hair-cloth, at the same time depressing his hands in such a manner that the most distant edge may have an inclination given it to turn upwards, and thus after striking upon the cloth it is immediately raised off. This shaking is continued by repeated strokes in quick succession, frequently changing its position, and continuing the dipping, and patting it frequently with the brush. By this process the hairs are just fixed in by the roots, without sinking too deeply, and a long flowing nap is obtained. The cotton and old stuff during the operation, sticking on the body of the hat by means of the hot liquor, preserve the nap from flying off; at the same time, by enabling it

it to hold a greater body of the fluid, the work is facilitated, and the nap is also preserved from the continued action of the brush.

When the nap is completely fastened, which will be in about half an hour, the cotton and old stuff is loosened by striking with a flat stick, and continuing the shaking. In a short time it will appear in a loose flake over the surface, which is taken off with the fingers whilst the nap remains fixed by the roots in the substance of the felt: the cotton and old stuff is dried and preserved for future use. In plating, as the bodies are first boiled, and as the nap laid on is of a soft, smooth nature, nothing is made use of in the kettle but clean water. Best stuff, hares' wool, neuter wool, seal wool, or a mixture of any of the stuffs, are made use of according to the intended quality. Neuter wool has a short, neat appearance as a nap; seal wool-naps are much esteemed, and wear remarkably well: for the best plates, some beaver is added to the other stuffs made use of.

It has lately become a practice to unite the common method of napping with that of plating in stuff hats, which have the name of *shake-offs* given them. After a slight nap is first rolled on, a second, and principal nap, is shaken on in the same manner as in plated hats. A shorter fur may in this manner be applied to advantage, or one of the usual length will produce a more showy nap.

Hats have been worn of various colours, but those most in use at present are black, drab, and white. The white hats, which are only intended for ladies and children, have a nap of rabbits' fur, selected from the white skins. Drab hats are also made of stuffs of the natural colour, assorted for that purpose. In dyeing black, the articles now in general use are logwood, of which Campeachy was the best, copperas, and verdigrease. French verdigrease is far superior to the English. For dyeing common cordy hats, the general proportions for twelve dozen are about twenty-four pounds of logwood, seven of copperas, and a quarter of a pound of verdigrease. The logwood is chipped, and left in the boiler to soak the preceding night; part of the copperas and verdigrease is then added and boiled with the logwood. The hats are each fastened on a block with a string tied round the band and boiled in the liquor, sometimes turning those nearest the surface, and placing a weight upon them to keep them under the liquor.

After boiling about an hour they are taken out and exposed to the air, while a fresh quantity is boiled in the kettle the same time as before. This boiling and airing is repeated several times according to the strength of the dye, the perfection required, or the nature of the materials to be dyed, as experience has shewn that the action of the atmospheric air, or the oxygen it contains, very much contributes to improve the dye; the remainder of the copperas and verdigrease is added in a decreased proportion to each suit. Common hats that are easily dyed have now generally two suits only; best hats from three to four.

On account of the high price of verdigrease, sulphate of copper or blue vitriol is frequently made use of in dyeing common hats in a larger proportion, or a mixture of about equal parts of each. But those dyed with verdigrease only have the brightest appearance after finishing. After dyeing, the hats are well washed in clean water.

The following is the method of dyeing practised in France: one hundred pounds of logwood, twelve pounds of gum, and six pounds of galls are boiled in a proper quantity of water for some hours; after which about six pounds of verdigrease and ten pounds of green vitriol are added, and the liquor kept just simmering, at a heat a little below boiling. Ten or twelve dozen hats are immediately put in, each on its block, and kept down by cross bars for about an hour and a half; they are then taken out and aired, and the same number of others put in their room. The two sets of hats are thus dipped and aired alternately eight times each, the liquor being refreshed each time with more of the ingredients, but in less quantity than at first. This account of dyeing must of course refer only to the better sort of hats.

We are not aware that gum has ever been used in this country; galls, on account of their price, are seldom used in England at present. A cheap substitute may be found in oak-bark, which we believe is not generally known among the hatters; and we should apprehend it might be employed to considerable advantage. It requires no other preparation than to be cut or coarsely broken, and it is said to furnish a dye much fuller, more beautiful and more durable.

The following is extracted from the report of the Lyceum of Arts: "Experiments were made by order of the College of Pharmacy at the Manufactory of Beaugolin and Morel. Two boilers of about 220 hats each were made ready; one for the gall-nuts, and the other for the bark. Twelve hats in each were marked: they were of the same stuff and the same size, had been prepared with all the precautions which each of the two methods required; and the whole process was carefully observed by a commissioner who attended for the purpose. After all these hats had been properly dried, cleaned, and brushed, they were placed indiscriminately on a table. Several of the most expert dyers in Paris were invited to select from the twenty-four hats the twelve which should appear to them to be best dyed. These dyers arrived separately at two different times, so that there were two selections; and in both cases, one hat excepted, these dyers pointed out as the best dyed those hats which had been treated with the oak bark."

In January 1782, Mr. Golding, of London, obtained a patent for dyeing hats green on the underside, a specification of which is published in the fifth volume of the Repertory. The principal difficulty in this process,

process, is to preserve the upper part of the brim, and the crown of the hat from the action of the dye. His method consisted in spreading over the upper surface, with a painter's brush, a thin paste made of flour or clay, and enclosing it in a funnel either of metal or wood to prevent the dye from penetrating. The hats are first boiled in alum and argil; and afterwards, Mr. Golding says, "in a dye prepared of fustic, turmeric, ebony, weld, safflower, saffron, indigo, and vitriol, with chamber-lye, or pearl-ash, at the option of the dyer; sometimes all used together, sometimes otherwise, according to the intention of the dyer, and to the colour required." If any portion of the dye has penetrated the hat, so as to occasion spots on the other side, they may be removed by washing with a strong warm alkaline liquor; but as yellow spots will afterwards remain, they are removed by means of a small quantity of either of the mineral acids. The green under-side hats are now generally stained without boiling, with a strong dye, which has for its basis a solution of indigo in the sulphuric acid. Sometimes the brim of the hat is composed of two separate pieces of felt, the under piece of which is first dyed green, and afterwards glued to the upper part.

It is necessary to observe, that soft water should always be made use of in dyeing; and as it is not readily obtained in some situations, the following method of communicating its properties to common hard water, may not be unacceptable. Twenty-four bushels of bran is put into a vessel capable of containing ten hogsheads. A large boiler is filled with water, and when just ready to boil is poured into the vessel. Soon after the acid fermentation begins, and in about twenty-four hours, the water is ready for use.

After the hats are dried, the next operation they undergo is that of stiffening. For the common purposes of stiffening, glue and vinegar dregs, beer grounds, or dregs from the distilleries, are the articles made use of. The hat, for this purpose, is put into the crown of another large one, called a stiffening-hat, which is only felted and blocked, and has its crown slit open to admit the hat to be stiffened, of any depth the more readily. These are placed in the hole of a plank, on which the brims are supported. The dregs are then first applied warm, with a brush similar to a large painting-brush, on the inside of the crown only; this is done by holding the brush in the right-hand, while the left-hand, holding the brim of the stiffening-hat, continually turns it round, that the enclosed may be uniformly covered with the dregs. The dregs are made use of as they are the cheapest mucilage, and give a degree of firmness to the hat, at the same time, preventing the glue from penetrating through to the surface. After this is dry, the glue is applied to the crown in the same manner, which is made in the proportion of about one pound of glue to three pints of water. After it is laid on with the brush, it is well rubbed round with the hand; for which purpose it is found expedient to employ a second person in the business, who receives the hat of the first person as fast as the glue is laid on with the brush. It was remarked that, in the first formation of the hat, the part designed for the band was laid thicker than any other; as this part has the most wear—as the wet is most likely to penetrate here—and as the general firmness of the hat depends on the strength of the band, it is likewise necessary to attend particularly to this part in the stiffening.

In stiffening a quantity of hats, the crowns only are thus attended to in the first place. In common hats, the grounds are frequently mixed with the glue, and laid on at the same time. The brims are next stiffened with a common soft brush, and glue only, which is applied to the underside. This is well worked into the body of the felt with the hand, and the hats are placed in a stove to dry. When dry, the nap on the underside of the brim will be glued down to the felt; this is removed from the surface by scouring it with a brush and a quantity of warm soap-suds; which is pressed out of the nap by the blunt edge of a wooden or copper stamper. Ladies' light hats, and some of the children's fancies, are stiffened with the application of starch, or common flour paste only.

In France, the composition of gum arabic, common gum of that country, and Flanders' glue, are employed for the purpose of stiffening. The brittleness of gum arabic has been found an inconvenience, and a substitute has been sought for in some simple preparation from their indigenous plants. M. Chaussier observes, that "mucilage is found in great quantity in many plants; it may easily be extracted by boiling; and a factitious gum, which is both supple and tenacious, may be formed by evaporation. These considerations led me to recommend, for the purpose of stiffening, a solution of glue in a strong and mucilaginous decoction of linseed. This preparation has been long used in the manufactory (of the Cote d'or); and is both more economical, and more conducive to the beauty of the work. Since that time, M. Margeron having communicated to me some observations respecting the mucilage which may be extracted from the leaves of the horse-chesnut tree, and having ascertained how great a quantity of mucilaginous and glutinous matter these leaves furnish, especially when the foliation is in full vigour, a solution of glue, in a strong decoction of them, has been used with great success." Perhaps this mucilage from the leaves of the horse-chesnut might be worthy the attention of the English hat-maker.

As glue is subject to the action of moisture, hats, stiffened of that material alone, are not perfectly waterproof. Several expedients have been devised to obviate this inconvenience: one of the methods, perhaps, most generally known, is that of *balling*. A ball is formed by melting about three parts rosin, four parts bees-wax, and two parts mutton suet. This is frequently rubbed over the inside part of the hat while planking, particularly over that part which is to form the band. After balling, the hats are stiffened with glue in the usual manner.

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In 1802, Messrs. Ovey and Jepsin, of London, obtained a patent for a method of water-proof stiffening. This was done by preparing a double hat; the under one was made of coarse materials, stiffened, and covered with a cement made of oue pound and three-quarters of flour, three quarts of water, one ounce of alum, and two ounces of rosin; the latter was finely pulverized, and added while the rest was boiling; stirring it together until dissolved. The under part of the finer outside casing was also covered with the same, and then placed over the other, and united together by pressing with a cool iron. Water-proof stiffening, particularly for best hats, has lately been much attended to, and various are the methods employed by different manufacturers; but nothing appears to have so completely answered the purpose, and, at the same time to have been so advantageous in wearing, as that of stiffening with a solution of caoutchouc, or gum-elastic. The exact method of the process is, at present, confined to a few hands, and industriously concealed from publicity.

The dry hat, after stiffening, is very rigid, and of an irregular figure; preparatory to finishing, therefore, it is fresh blocked. For this purpose, it is necessary to soften the glue, which is done by the operation of steam. A hot iron is placed within a circular wooden frame, on which a wet cloth is thrown; the crown of the hat is then laid over the rising steam, whilst the brim rests on the frame; and thus it is soon rendered sufficiently soft to receive the impression of a block of the intended size and shape. By the use of a hot iron, generally from twenty to twenty-five pounds in weight, a small card, brushes, &c., with the addition of water, the nap has the requisite direction given it, and receives its smoothness, and polish. Minute directions here, are unnecessary; the judgment of the workman must be his principal director. It may not be useless to remark, that in watering the hats, which is done with a soft wetting-brush for that purpose, the giving them plenty of water, and quickly passing a pretty hot iron over them, gives the glue a firmness and smartness, in which it will be deficient by more cautious wetting, and more dilatory operations. If a little glue is accidentally drawn through the hat, by the heat of the iron, a wetted brush is laid on the iron a little to heat it sufficiently; and by the application of the warm, moist brush, and carding, it is soon extracted. Instead of water, oil was formerly used in finishing all descriptions of hats, and, for the coarsest sort of wool hats, the practice has prevailed till very lately.

The instrument generally made use of for cutting the brims of round hats, is merely a small worn-out card. At the outer edge a number of notches is cut for the purpose of inserting the point of a knife. The inner edge of the card, and the handle, is placed close to the crown of the hat, while on the block; and by placing the point of a knife in the proper notch, and drawing it round with the card, still keeping it close to the crown, the brim is evenly cut to any required dimensions. The hat is put in shape by curling the edges with the iron over a small rope for that purpose, stretching the hat out in an oval form by placing a screw or common stick across, and forming the brim with the hands while it is warm. The coarse hairs are picked out of the fine hats with a pair of steel prickers, and then given to be lined and bound; after which, it receives the last finish, and is ready for the wearer.

Some years ago, Mr. Hance, of Tooley-street, Southwark, obtained a patent for a method of rendering beaver and other hats water-proof, which is thus described:—He takes a thin shell made of wool, hair, and fine beaver, to form the crown of the hat, and another shell, or plate, of the same materials, for the brim. These parts are to be dyed black, and finished without glue or other stiffening, in order that they may not be injured by the rain, which, in other beaver hats, after being exposed to a heavy shower, draws out the glue and sticks down the nap, and makes it appear old and greasy. The shell may be made in one piece only, in the shape of the hat, blocked deep enough to admit of the brim being cut from the crown: the under side of the shell and the inside of the crown, must then be made water-proof, by first laying on a coat of size or thin paste, strong enough to bear a coat of copal-varnish, and, when thoroughly dry, another coat of boiled linseed oil. When dry, the crown must be put on a block, and a willow or cotton body or shape, wove on purpose, put into the inside of the crown and cemented in it. When dry, it must be finished with a hot iron, and the crown is done. The brim must, in like manner, be cemented to a substance or body made with willow, or other fit material sufficiently thick to make the inside of the brim. The brim and body are now to be pressed together, after which, the under side of the brim may be covered with another shell of beaver or silk shag. The crown and brim are now to be sewed together: the edge of the brim must be oiled and varnished with copal-varnish and boiled linseed-oil, to prevent any rain getting in. The cement used, for sticking the parts together, may be made with one pound of gum Senegal, one pound of starch, one pound of glue, and one ounce of bees-wax, to be boiled in a quart of water. Hats made in this way, require only to be wiped dry after they have been exposed to the heaviest rain.

Hats are likewise made, for women's wear, of chips, straw, or cane, by platting, and sewing the plats together, beginning with the centre of the crown, and working round till the whole is finished. Hats, for the same purpose, are also woven, and made of horse-hair, silk, and other substances. There are few manufactures in the kingdom in which so little capital is required, or the knowledge of the art so soon obtained, as in that of straw-platting. One guinea is quite sufficient for the purchase of the machines and materials for employing a hundred persons for some months. The straw is cut at the joints, and the outer skin or covering being removed, it is sorted into bundles of equal sizes,

sizes, of eight or ten inches in length, and a foot in circumference. The straws, thus prepared, are to be dipped in water, and when the moisture is shaken out, the bundles are set on their edges, in a box, which is sufficiently close to prevent the evaporation of smoke. In the middle of the box is an earthen dish, containing brimstone, broken in small pieces or roughly pounded, which is set on fire, and the box covered over and kept in the open air a few hours. The next thing to be performed, is, the splitting of the straws, and one person, with the help of a small machine, will split as many as fifty braiders can work up. The straws when split, are termed splints of which each worker has a certain quantity: on one end is wrapped a linen cloth, which is held under the arm, and the straws drawn out as wanted. Platters should acquire the habit of using their second fingers and thumbs, instead of the fore-fingers, which are often required to assist in turning the splints, and very much facilitate the platting. Each platter should have a small linen work-bag, and a piece of paste-board to roll the plat round. After five yards have been worked up, it should be wound about a piece of board half a yard wide, fastened at the top with yarn, and kept there several days to form it into a proper shape. Four of these parcels, or a score, is the measurement by which the plat is sold.

We shall now give the specification of Mr. Peter Boileau's patent for a new and improved manufacture of straw into hats, bonnets, &c. which is as follows:—

Prepare the straw by separating it at each joint, and taking off all the outside skin or covering. One end must be cut pointed, that is, in the form of a pen, that it may be inserted into the hollow of another, as it is worked. It must then be immersed in water, so that the water may pass through its tube, which takes off its brittleness, and makes it work uniform, take the shape of the block, and preserve its natural shape. The straw, being thus prepared, take a mould of wood, or other material, exactly of the form or shape of the crown of the hat, bonnet, or other article you propose to make; and, at the top of it, from the centre, draw or describe a small circle; from that circle, draw or describe perpendicular, serpentine, diagonal, or other lines or curves, as fancy may dictate. As those lines or curves form the ribs or separations of the work when complete, at the top of each of these lines or curves, where they touch the circle, fix a small nail, or pin; to which tie or fasten a double wire, covered or uncovered, which wire must be twice the length of the line or curve, and tied or fastened to the nail or pin, just in the middle of the wire, that there may be two equal ends of wire to work. Begin working, by introducing the pipe or quill straw betwixt the two wires; which wire must be drawn tight, and even with the line or curve. Repeat the same at every line or curve round the block; that is to say, let one wire go over, and the other under, the straw, at every line or curve. To the end of it join the straw, by introducing the sharp end of another straw into the former, just at the line or curve, and continue thus to the bottom of the block. To make the brim of the hat, or bonnet, or to perform any flat work, take a sheet of thick paste-board, and, after drawing the circle, for a hat or bonnet, formed by the bottom of the crown, and for other flat work at will, draw lines or curves according to fancy, as before; and, instead of nails or pins, as described, to be fixed into the block, make two small holes at the top of the lines or curves on the circle, through which pass the wire, and tie it in the same manner as to the nails or pins. When finished, the brim is to be sewed, or otherwise fixed, to the crown, or it may be continued to be worked on the paste-board to the crown, so that the hat or bonnet shall be all in one piece, without separation. Fix or place, in the space left by the circle at the top of the crown, a device of straw, or any other ornament, and likewise round the edge of the brim, when the work will be complete. It may be observed, that, being worked with wire, a variety of form or shape may be obtained, without injury to the work.

JAPANNING.

Japanning is the art of varnishing and drawing figures on wood, in the same manner as is done by the natives of Japan, in the East Indies. The substances which admit of being japanned are almost every kind that are dry and rigid, or not too flexible; as wood, metals, leather, and paper prepared.

The varnish said to be used in China and Japan is composed of turpentine and a curious sort of oil, which they boil up to a proper consistence. Persons who work in this business are liable to swellings and inflammations in the hands and face, but these are produced from the lack and not from the varnish. The lack is the sap or juice of a tree, which flows on cutting the lower part of the trunk of the tree, and is received in

vessels set on purpose under the incisions. This juice is of the colour and consistence of cream, when it runs from the tree, but as it comes in contact with the air, it becomes black. It is only used in this state; the method of preparing it is to set it out in the open air, in large flat bowls, and that the whole may be of the same uniform colour, it is kept continually stirring for many hours, almost without intermission. By this method it becomes of a fine deep black; burnt wood is now mixed with it, and then spreading it thin over any board or substance which they mean to japan, they dry it in the sun, and it is soon harder than the board on which it is laid. When this is quite dry it is polished with a smooth stone and water, till it is as even as glass, and then, wiping it dry, they lay on the varnish, made of oil and turpentine. If the work is to be of any other colour than black, that colour is to be mixed with the varnish, and then the whole spread on evenly and thin, because on this depends the principal art of varnishing. When there are to be figures in gold and silver, these must be traced out with a pencil in the varnish, over the rest of the work; and when this varnish is almost dry, the leaf-gold, or silver, is to be laid on, and polished afterwards with some smooth substance.

Wood and metals do not require any other preparation, but to have their surface perfectly even and clean: but leather should be securely strained either on frames or on boards: as its bending or forming folds would otherwise crack and force off the coats of varnish: and paper should be treated in the same manner, and have a previous strong coat of some kind of size; but it is rarely made the subject of japanning till it is converted into papier machè, or wrought by other means into such form that its original state, particularly with respect to flexibility, is lost.

One principal variation from the method formerly used in japanning is, the using or omitting any priming or undercoat on the work to be japanned. In the older practice, such priming was always used; and is at present retained in the French manner of japanning coaches and snuff-boxes of the papier machè; but, in the Birmingham manufacture here, it has been always rejected. The advantage of using such priming or under-coat is, that it makes a saving in the quantity of varnish used; because the matter of which the priming is composed fills up the inequalities of the body to be varnished; and makes it easy, by means of rubbing and water-polishing, to gain an even surface for the varnish; and this was, therefore, such a convenience in the case of wood, as the giving a hardness and firmness to the ground was also in the case of leather, that it became an established method; and is, therefore, retained even in the instance of the papier machè by the French, who applied the received method of japanning to that kind of work on its introduction. There is, nevertheless, this inconvenience always attending the use of an under-coat of size, that the japan coats of varnish and colour will be constantly liable to be cracked and peeled off by any violence, and will not endure near so long as the bodies japanned in the same manner, but without any such priming; as may be easily observed in comparing the wear of the Paris and Birmingham snuff-boxes; which latter, when good of their kind, never peel or crack, or suffer any damage, unless by great violence, and such a continued rubbing as wastes away the substance of the varnish; while the japan coats of the Parisians crack and fly off in flakes, whenever any knock or fall, particularly near the edges, expose them to be injured. But the Birmingham manufacturers, who originally practised the japanning only on metals, to which the reason above given for the use of priming did not extend, and who took up this art of themselves as an invention, of course omitted at first the use of any such under-coat; and not finding it more necessary in the instance of papier machè than on metals, continue still to reject it. On which account, the boxes of their manufacture are, with regard to the wear, greatly better than the French.

The laying on the colours in gum-water, instead of varnish, is also another variation from the method of japanning formerly practised; but the much greater strength of the work, where they are laid on in varnish or oil, has occasioned this way to be exploded with the greatest reason in all regular manufactures: however, they who may practise japanning on cabinets, or other such pieces as are not exposed to much wear and violence, for their amusement only, and, consequently, may not find it worth their while to encumber themselves with the preparations necessary for the other methods, may paint with water-colours on an under-coat laid on the wood, or other substance, of which the piece to be japanned is formed; and then finish with the proper coats of varnish, according to the methods below taught; and if the colours are tempered with the strongest isinglass, size, and honey, instead of gum-water, and laid on very flat and even, the work will not be much inferior in appearance to that done by the other method, and will last as long as the old japan.

Priming.—The priming is of the same nature with that called clear-coating, by the house-painters; and consists only in laying on and drying in the most even manner, a composition of size and whiting, or, sometimes, lime instead of the latter. The common size has been generally used for this purpose: but where the work is of a nicer kind, it is better to employ the glovers', or the parchment size; and if a third of isinglass be added, it will be still better, and, if not laid on too thick, is much less liable to peel and crack. The work should be prepared by this priming, by being well smoothed with the fish-skin or glass-shaver, and, being made thoroughly clean, should be brushed over once or twice with hot size, and diluted with two-thirds of water, if it be of the common strength. The priming should then be laid on with a brush as evenly as possible; and should be formed of a size whose consistence is betwixt the common kind and glue, mixed with as much whiting as will

give

give it a sufficient body of colour to hide the surface of whatever it is laid upon, but not more.

If the surface be very clean on which the priming is used, two coats of it laid on in this manner will be sufficient; but if, on trial with a fine wet rag, it will not receive a proper water-polish on account of any inequalities not sufficiently filled up and covered, one or more coats must be given it; and whether a greater or less number be used, the work should be smoothed, after the last coat but one is dry, by rubbing it with the Dutch rushes. When the last coat is dry, the water-polish should be given, by passing over every part of it with a fine rag gently moistened, till the whole appear perfectly plain and even. The priming will then be completed, and the work ready to receive the painting, or coloured varnish: the rest of the proceedings being the same in this case as where no priming is used.

When wood or leather is to be japanned, and no priming is used, the best preparation is to lay two or three coats of coarse varnish, composed in the following manner:—Take of rectified spirits of wine one pint, and of coarse seed-lac and resin, each, two ounces. Dissolve the seed-lac and resin in the spirit; and then strain off the varnish. This varnish, as well as all others formed of spirits of wine, must be laid on in a warm place; and, if it can be conveniently managed, the piece of work to be varnished should be made warm likewise; and, for the same reason, all dampness should be avoided; for either cold or moisture chills this kind of varnish, and prevents it taking proper hold of the substance on which it is laid.

Japan-Grounds.—When the work is so prepared, or by the priming with the composition of size and whiting above described, the proper japan-ground must be laid on, which is much the best formed of shell-lac varnish, and the colour desired, if white be not in question, which demands a peculiar treatment, or great brightness be not required, when also other means must be pursued. The colours used with the shell-lac varnish may be any pigments whatever, which give the tint of the ground desired; and they may be mixed together to form browns or any compound colours.

As metals never require to be under-coated with whiting, they may be treated in the same manner as wood or leather, when the under-coat is omitted, except in the instances referred to below.

White Japan-Grounds.—The forming a ground perfectly white, and of the first degree of hardness, remains hitherto a desideratum, or matter sought for, in the art of japanning, as there are no substances which form a very hard varnish but what have too much colour not to injure the whiteness, when laid on of a due thickness over the work. The nearest approach, however, to a perfect white varnish, already known, is made by the following composition:—Take flake-white, or white-lead, washed over and ground up with a sixth of its weight of starch, and then dried; and temper it properly for spreading with the mastich-varnish. Lay these on the body to be japanned, prepared either with or without the under-coat of whiting, in the manner as above ordered; and then varnish it over with five or six coats of the following varnish;—Provide any quantity of the best seed-lac, and pick out of it all the clearest and whitest grains, reserving the more coloured and fouler parts for the coarse varnishes, such as that used for priming or preparing wood or leather. Take of this picked seed-lac two ounces, and, of gum animi, three ounces, and dissolve them, being previously reduced to a gross powder, in about a quart of spirit of wine, and strain off the clear varnish.

The seed-lac will yet give a slight tinge to this composition, but cannot be omitted where the varnish is wanted to be hard; though, when a softer will answer the end, the proportion may be diminished, and a little crude turpentine added to the gum-animi to take off the brittleness.

A very good varnish, free entirely from all brittleness, may be formed by dissolving as much gum-animi as the oil will take, in old nut or poppy oil, which must be made to boil gently when the gum is put into it. The ground of white colour itself may be laid on in this varnish, and then a coat or two of it may be put over the ground; but it must be well diluted with oil of turpentine when it is used. This, though free from brittleness, is nevertheless liable to suffer by being indented or bruised by any slight strokes; and it will not well bear any polish, but may be brought to a very smooth surface without, if it be judiciously managed in the laying it on. It is likewise somewhat tedious in drying, and will require some time where several coats are laid on; as the last ought not to contain much oil of turpentine.

Blue Japan Grounds.—Grounds may be formed of bright Prussian blue, or verditer glazed over by Prussian blue, or of smalt. The colour may be best mixed with shell-lac varnish, and brought to a polishing state by five or six coats of varnish of seed-lac: but the varnish, nevertheless, will somewhat injure the colour by giving to a true blue a cast of green, and fouling, in some degree, a warm blue by the yellow it contains; where, therefore, a bright blue is required, and a less degree of hardness can be dispensed with, the method before directed in the case of white grounds must be pursued.

For a scarlet japan ground, vermilion may be used: but the vermilion has a glaring effect that renders it much less beautiful than the crimson produced by glazing it over with carmine or fine lake; or even with rose-pink, which has a very good effect used for this purpose. For a very bright crimson, nevertheless, instead of glazing with carmine the Indian lake should be used, dissolved in the spirit of which the varnish is compounded, which it readily admits of when good; and in this case, instead of glazing with the shell-lac varnish, the upper or polishing coats need only be used, as they will equally receive and convey the tinge of the Indian

Indian lake, which may be actually dissolved by spirit of wine; and this will be found a much cheaper method than the using carmine. If, nevertheless, the highest degree of brightness be required, the white varnishes must be used.

For bright yellow grounds, the king's yellow, or the turpeth mineral should be employed, either alone or mixed with fine Dutch pink; and the effect may be still more heightened by dissolving powdered turmeric root in the spirit of wine, of which the upper or polishing coat is made; which spirit of wine must be strained from off the dregs before the seed-lac be added to it to form the varnish.

Green grounds may be produced by mixing the king's yellow and bright Prussian blue, or rather the turpeth mineral and Prussian blue; and a cheap but less perfect kind by verdigris with a little of the abovementioned yellows or Dutch pink. But where a very bright green is wanted, the crystals of verdigris, called distilled verdigris, should be employed; and to heighten the effect, they should be laid on a ground of leaf-gold, which renders the colour extremely brilliant and pleasing.

Orange-coloured japan grounds may be formed by mixing vermilion or red lead with king's yellow or Dutch pink, or the orange-lac, which will make a brighter orange ground than can be produced by any mixture.

Purple japan grounds may be produced by the mixture of lake and Prussian blue; another kind may be made by vermilion and Prussian blue. They may be treated as the rest with respect to the varnish.

Black grounds may be formed by either ivory-black or lamp-black: but the former is preferable where it is perfectly good. These may be always laid on with shell-lac varnish, and have their upper or polishing coats of common seed-lac varnish, as the tinge or fulness of the varnish can be here no injury.

For forming the common black japan grounds by means of heat on metal, the piece of work to be japanned must be painted over with drying oil; and when it is of moderate dryness, must be put into a stove of such a degree of heat as will change the oil to black, without burning it so as to destroy or weaken its tenacity. The stove should not be too hot when the work is put into it, nor the heat increased too fast, either of which errors would make it blister; but the slower the heat is augmented, and the longer it is continued, provided it be restrained within the due degree, the harder will be the coat of japan. This kind of varnish requires no polish, having received when properly managed, a sufficient one from the heat.

The best kind of tortoise-shell ground produced by heat is not less valuable for its great hardness, and enduring to be made hotter than boiling water without damage, than for its beautiful appearance. It is to be made by means of a varnish prepared in the following manner: take of good linseed-oil one gallon, and of umber half a pound; boil them together till the oil become very brown and thick; strain it then through a coarse cloth, and set it again to boil, in which state it must be continued till it acquire a pitchy consistence, when it will be fit for use.

Having prepared thus the varnish, clean well the metal plate which is to be japanned; and then lay vermilion tempered with shell-lac varnish, or with drying oil diluted with oil of turpentine, very thinly, on the places intended to imitate the more transparent parts of the tortoise-shell. When the vermilion is dry, brush over the whole with the black varnish, tempered to a due consistence with oil of turpentine; and when it is set and firm, put the work into a stove, where it may undergo a very strong heat, and be continued a considerable time; if even three weeks or a month, it will be the better.

This was given amongst other receipts by Kunckel; but appears to have been neglected till it was revived with great success in the Birmingham manufactures, where it was not only the ground of snuff-boxes, dressing-boxes, and other such lesser pieces, but of those beautiful tea-waiters which have been so justly esteemed and admired in several parts of Europe where they have been sent. This ground may be decorated with painting and gilding in the same manner as any other varnished surface, which had best be done after the ground has been duly hardened by the hot stove; but it is well to give a second annealing with a more gentle heat after it is finished.

Method of painting Japan Work.—Japan work ought properly to be painted with colours in varnish, though, in order for the greater dispatch, and in some very nice works in small, for the freer use of the pencil, the colours are frequently tempered in oil; which should previously have a fourth part of its weight of gum animi dissolved in it; or, in default of that, of the gums sandarac or mastic. When the oil is thus used it should be well diluted with spirit of turpentine, that the colours may be laid more evenly and thin; by which means fewer of the polishing or upper coats of varnish become necessary.

In some instances water colours are laid on grounds of gold, in the manner of other paintings; and are best when so used in their proper appearance, without any varnish over them; and they are also sometimes so managed as to have the effect of embossed work. The colours employed in this way for painting, are both prepared by means of isinglass size corrected with honey or sugar-candy. The body of which the embossed work is raised, need not, however, be tinged with the exterior colour, but may be best formed of very strong gum-water, thickened to a proper consistence by bole-armenian and whiting in equal parts; which being laid on the proper figure and repaired when dry, may be then painted with the proper colours tempered in the isinglass size, or in the general manner with shell-lac varnish.

Method of varnishing Japan Work.—The last and finishing part of japanning lies in the laying on and polishing

polishing the outer coats of varnish; which are necessary, as well in the pieces that have only one simple ground of colour, as with those that are painted. This is in general best done with common seed-lac varnish, except in the instances and on those occasions where we have already shewn other methods to be more expedient: and the same reasons which decide as to the fitness or impropriety of the varnishes, with respect to the colours of the ground, hold equally with regard to those of the painting: for where brightness is the most material point, and a tinge of yellow will injure it, seed-lac must give way to the whiter gums; but where hardness and a greater tenacity are most essential, it must be adhered to: and where both are so necessary, that it is proper one should give way to the other in a certain degree reciprocally, a mixed varnish must be adopted.

This mixed varnish, as we have already observed, should be made of the picked seed-lac. The common seed-lac varnish, which is the most useful preparation of the kind hitherto invented, may be thus made: take of seed-lac three ounces, and put it into water to free it from the sticks and filth that are frequently intermixed with it; and which must be done by stirring it about, and then pouring off the water and adding fresh quantities in order to repeat the operation till it be freed from all impurities, as it very effectually may be by this means. Dry it then and powder it grossly and put it with a pint of rectified spirit of wine into a bottle, of which it will not fill above two-thirds. Shake the mixture well together, and place the bottle in a gentle heat till the seed appear to be dissolved, the shaking being in the mean time repeated as often as may be convenient; and then pour off all that can be obtained clear by this method, and strain the remainder through a coarse cloth. The varnish thus prepared must be kept for use in a bottle well stopt.

When the spirit of wine is very strong, it will dissolve a greater proportion of the seed-lac: but this will saturate the common, which is seldom of a strength sufficient for making varnishes in perfection. As the chilling, which is the most inconvenient accident attending those of this kind, is prevented, or produced more frequently, according to the strength of the spirit; we shall therefore take this opportunity of showing a method by which weaker rectified spirits, may with great ease at any time be freed from the phlegm, and rendered of the first degree of strength.

Take a pint of the common rectified spirit of wine, and put it into a bottle of which it will not fill above three parts. Add to it half an ounce of pearl-ashes, salt of tartar, or any other alkaline salt, heated red-hot and powdered as well as it can be without much loss of its heat: shake the mixture frequently for the space of half an hour, before which time a great part of the phlegm will be separated from the spirit, and will appear together with the undissolved part of the salts in the bottom of the bottle. Let the spirit then be poured off or freed from the phlegm and salts by means of a tritorium or separating funnel; and let half an ounce of the pearl-ashes, heated and powdered as before, be added to it, and the same treatment repeated. This may be done a third time if the quantity of phlegm separated by the addition of the pearl-ashes appear considerable. An ounce of alum, reduced to powder and made hot but not burnt, must then be put into the spirit, and suffered to remain some hours, the bottle being frequently shaken: after which, the spirit, being poured off from it, will be fit for use.

The manner of using the seed-lac or white varnishes is the same, except with regard to the substance, used in polishing; which, where a pure white or great clearness of other colours is in question, should be itself white: whereas the browner sorts of polishing dust, as being cheaper and doing their business with greater dispatch, may be used in other cases. The pieces of work to be varnished should be placed near a fire, or in a room where there is a stove and made perfectly dry; and then the varnish may be rubbed over them by the proper brushes made for that purpose, beginning in the middle and passing the brush to one end; and then with another stroke from the middle passing it to the other. But no part should be crossed or twice passed over in forming one coat, where it can possibly be avoided. When one coat is dry another must be laid over it; and this must be continued at least five or six times or more, if on trial there be not sufficient thickness of varnish to bear the polish without laying bare the painting, or the ground colour underneath.

When a sufficient number of coats is thus laid on, the work is fit to be polished; which must be done, in common cases, by rubbing it with a rag dipped in Tripoli or pumice-stone, commonly called rotten stone, finely powdered; but towards the end of the rubbing a little oil of any kind should be used along with the powder; and when the work appears sufficiently bright and glossy, it should be well rubbed with the oil alone to clean it from the powder, and give it a still brighter lustre. In the case of white grounds, instead of the Tripoli or pumice-stone, fine putty or whiting must be used, both which should be washed over to prevent the danger of damaging the work from any sand or other gritty matter that may happen to be commixed with them.

It is a great improvement of all kinds of japan work to harden the varnish by means of heat, which in every degree that it can be applied short of what would burn or calcine the matter tends to give it a more firm and strong texture. Where metals form the body, therefore, a very hot stove may be used, and the pieces of work may be continued in it a considerable time; especially if the heat be gradually increased; but where wood is in question, heat must be sparingly used, as it would otherwise warp or shrink the body so as to injure the general figure.

MASONRY.

Masonry, includes, in practical architecture, the hewing of stones into the various shapes required in the multiplied purposes of building, the assembling them together by joints, level, perpendicular or otherwise, by the aid of cement, iron, lead, &c., the well doing of which requires much practical dexterity, with some skill in geometry and mechanics. It will be necessary to divide it into several ramifications, arising partly from local necessity, which has been in some measure its parent through all its vicissitudes, and which may be said to have followed the rise and fall of empires.

Masonry, in Egypt, Greece and Italy, consisted chiefly in performing works almost incredible in their extent and in the use of materials, equally so if considered in detail. These countries seem to have been favoured in every way to be eternalized; they abounded in porphyries and marbles, which the people found the means of extracting in pieces better adapted to promote magnificence in their works than contrivance in their arrangement. Modern masonry has consisted more in piling stone on stone to a vast height than in covering extent of plan, in which has been developed adequate skill if not magnificence. Considering it as an handicraft art, the institutions of Egypt tended most towards promoting its exquisiteness. Trades and even professions having been there hereditary, the way of life of each individual became predestined, his ambition consequently circumscribed, and his exertions hence limited to the working only according to a scale given him, and without any other consideration. In Greece, where a more liberal policy prevailed, we see the artist and the artisan united, the one in conceiving and the other in giving substance and effect to his conceptions; here masonry preserved all the beauty of the rigid Egyptian school, improved and expanded so as to have given life and health as it were to Art itself. It is impossible in the study of architecture (as it was in Greece during its perfection) not to admire the skill of her artisans; for although the mechanical contrivance must have been previously arranged by the architect; yet to effect this, much must have remained to the care of the mason.

It is abundantly proved that the ancient Egyptians were intimately acquainted with the process of hardening metal, without which little could have been done in working marble: the mason requiring few other tools except what are of hardened metal. The triangle, square, and plumb-line, &c., assist him in fixing what he has previously reduced by the mallet and chisel to its required dimension and shape. As to the raising ponderous columns, architraves, and cornices to their appointed destinations, of which there are numerous astonishing instances still in existence, this must have depended more on machinery of great power, or in some instances, as is more probable, on the inclined plane than on the mason: for it was the practice of the ancients in works of great magnitude to prepare, and that often at the quarry, so much only of the column, architrave, &c. as immediately referred to its joinings, leaving the detail or mouldings to be worked and formed after the blocks had reached their destinations, and to this circumstance perhaps are to be attributed no small part of their present sharpness and brilliancy. Many of the columns in the temples in Upper Egypt are entirely of one piece of granite, and when of more they were so minutely joined (and without cement) as to defeat detection. In the Temple of Hermopolis, such are the colossal proportions, that the diameter of the columns is eight feet ten inches each, and they are placed at equal intermediate distances; so that the space between the two middle columns within which the gate is included is twelve feet, the portico is 120 feet, and its height is sixty feet. The architrave is composed of five stones twenty-two feet long, and the frieze of as many. The only remaining stone of the cornice is thirty-four feet. These particulars will convey an idea both of the power and skill which the Egyptians possessed to raise enormous masses, and the magnificence of the materials which they employed; but in using such colossal materials it was almost impracticable to employ cement in their joinings, the weight of the mass alone being adequate to ensure their solidity. The Pyramids afford another instance of elaborate masonry; and it may be here remarked that it is only governments sacerdotally despotical who could dare to undertake to build them, and people stupidly fanatical who could contribute to their execution: but, to speak of them as they are, Grobert estimates the base of that of Cheops to 720 feet and its height 448 feet; that of Chephrenes 655 feet and 390 in height; and there is one somewhat smaller. They are wholly composed of large blocks of granite so interwoven by the skill of the architect and mason as to have defied

defied the ravages of man and time. These blocks are united together by being crossed and bonded, the joints being constantly made over each solid, and the parts which secured the sarcophagus are dovetailed together. Walls of this nature were used by the Greeks, and called emplection: and Vitruvius says, "The faces of stones in walls of this kind are smooth; the rest is left as it grows in the quarry, being secured by alternate joints and mortar. The ancients made use of several sorts of walls, in all which they appear to have considered it indispensable to employ more or less of masonry. They had their reticulated walls, and also the uncertain: of these two the reticulative kind is the most handsome; but the joints are so ordered that in all parts the courses have an inferior position; whereas in the uncertain the materials rest firmly one upon another, and are interwoven together, so that they are much stronger than the recticulated, though not so handsome. In this kind of wall the courses were always level, but the upright joints were not ranged regularly or perpendicularly to each other in the alternate courses, nor in any other respect correspondently, but were disposed uncertainly, according to the accidental size of the stone or brick. Thus our bricks are commonly ranged in ordinary walls, in which all that is regarded is that the upright joints in two adjoining courses do not coincide (See article Bricklaying for English and Flemish Bond). Both these sorts of walls are formed of very small pieces that they may be saturated with mortar, which adds greatly to their solidity.

To saturate a wall with mortar is a practice which ought to be had recourse to in every case practicable in which brick or small stones are made use of. It consists in saturating fresh lime with water, and pouring it while hot among the masonry in the body of the wall.

The walls called by the Greeks Isodomum, is when all the courses were of an equal thickness, and Pseudosodomum or false when they were unequal. Both these walls are firm in proportion to the compactness of the mass and the solid nature of the stones, which when so, they do not absorb the moisture from the mortar, but it preserves its humidity to a great age; and being situated in regular and level courses the mortar is prevented from falling; and the whole thickness of the wall being united it endures almost perpetually. In the wall called emplection the faces of the stones are smooth, the rest is left as it comes from the quarry, being secured with alternate joints and mortar. This kind of building admits of greater expedition, as the artificer can quickly raise a case or shell which serves for the two faces of the work, filling up the middle with rubble-work and mortar. Walls of this kind therefore consist of three coats, two being the faces and one the rubble core, which is in the middle; but the great works of the Greeks were not done in this manner; they not only built the facing courses regularly but also the alternate joints through the whole thickness, not ramming the middle with rubble but building it the same as the face, and of one united coat constructed the wall: besides this, they often disposed single pieces, which they called diatonos,* in the thickness of the wall, extending from one surface to the other, which bound and exceedingly strengthened the wall. It is imperious on those, therefore, who are intrusted with works requiring great strength as well as durability, to weigh and consider well the different ways of uniting the several parts of the masonry of a wall, without which no work can be effected with credit.

The Roman emplection had sometimes partial cores of rubble work or brick, many examples of which still exist, which is a sufficient proof of its strength and durability; but the Greeks wrought their walls throughout in the same manner as the facings or fronts, as their temples now existing testify, which manner of working no doubt they received from the Egyptians, both countries having aimed to eternalize its monuments.

At the revival of the arts in Europe in the fifteenth century, Italy abounded in ancient examples, on which the wealth of the world had been exhausted. The artist and the artisan, although perhaps with equal zeal to their predecessors, found the means inadequate to effect works of the description from which they had formed their studies. Hence arose the miserable expedients in modern masonry, to enumerate which is only to consecrate its poverty, and to emblazon its pigmy efforts, for such they are compared to the great works of Egypt, Greece, and Rome; in the former of which countries whole quarries were wrought into sumptuous temples, approached through avenues of marble, leagues in extent, sculptured into sphinxes, obelisks, &c. so much so that a modern traveller, who has witnessed the ruins, remarked, "while examining the mass, the imagination becomes fatigued with the mere thought of describing it. In the temple of Karnac, the portico alone contains 100 columns, the smallest of which is seven feet and a half in diameter and the largest eleven feet. The space occupied by its circumvalation contains lakes and mountains; while avenues of sphinxes reach even to the very gates. In short, to form a competent idea of so much magnificence, it is necessary the reader should fancy what is before him to be a dream, for even the spectator cannot believe his eyes."

Modern masonry is confined more to the working in freestone than in marble, in the former of which these islands abound, which offer many facilities arising from the nature of its quality in reducing it to all the required shapes in modern construction. At Bath and all the Western counties they saw it by a toothed saw into smaller scantling, which is again cut by the mason with a hand-saw, and afterwards hewn by an axe, then dragged and smoothed in the same way, according to the required situation or the quality of the proposed work for which the stone is intended. The workman's tools.

* All these several kinds of walls, made use of in building by the ancient Greeks and Romans, are to be seen by referring to Newton's Vitruvius, vol. I.

tools consist of a hand-saw similar to what is made use of by carpenters; a drag, which is commonly nothing more than a piece of an old saw. He has also his chisels and gouges, gauges and moulds for his sunk and moulded work, which are all afterwards cleaned up by the drag. In Gloucestershire, the masons often use planes for their mouldings, the stones there being more crisp and not intersected by shells, &c., which prevent their general adoption with regard to many other freestones.

Portland freestone is the common stone made use of by the masons in London, which is brought from the island of that name in blocks of almost all dimensions roughly hewn. Its hardness gives it many requisites to produce exquisite masonry. It is sawn into scantling by the friction of sharp siliceous earth and water by means of a framed plate saw of iron. It is afterwards worked by the mallet and chisel to the required form, and then rubbed to a smooth face with sand or grits by hand. Most of our public buildings are composed of this stone; and it has been the practice to make use of it in private ones for the kerbs, strings, fascias, columns, cornices and balustrades, when all the other parts were of other materials. Internally, for the floors of halls, vestibules, staircases, &c. Portland stone is decidedly the handsomest freestone known, and capable of bearing as fine an arras in moulding as marble, which is the probable reason of its preference, although many other freestones might be obtained at half the original cost and without its great additional expense of freight and duty. The two latter, however, has risen so high of late that the Gloucestershire stone is now at the wharfs as its competitor, and is daily coming more into use, and perhaps may in a few years in some measure supersede it; it having been already employed in several works of consequence, in which it has been found to answer the purpose best; and as the masons get more used to it Portland stone will be discontinued, excepting for the internal work, where it will always be preferred from its superior neatness.

The granites of Cornwall and that called Dundee stone from North Britain are now employed for all works in which great solidity and wear are required. It has been sought for and used at the several Docks, also at the new Bridges. Its excessive hardness is as much the terror of the London masons as the Gloucestershire stone is for its softness; on account of which has arisen the necessity of bringing to London the workmen as well as the stone, there not having been found persons in London who would undertake to work it. The bringing round of the granites to London and other places arose in the first instance from the necessity of finding something more solid and durable for the locks and basons of canals. The freestone of the neighbourhood having been generally found inadequate, these demands gave rise to the more multiplied working of the several quarries. Hence it is that now all these different qualities of stone are regularly to be found in the markets, and modern masons will henceforth have the credit of effecting more lasting works than those from freestone, by a judicious blending and arrangement of all the several qualities of stones to the various purposes of strength and ornament, than they have hitherto had it in their power to do. A substantial foundation is of the first importance in masonry, without which no work can be considered as durable. However, in modern construction this vital part of a building is almost usually intrusted to the carpenter and bricklayer; the former for the purpose of piling such ground as is found inferior, soft, and marshy, and to the latter to raise the needful walls in the substructure in which little or no masonry is employed. Some architects latterly have abandoned planking, many dilapidations having been occasioned by its decay.

Planking consists in bedding strong boards of oak or fir the whole length and breadth of the proposed foundation; the former should never be less than three inches and the latter five inches in thickness. And it would be a wise precaution to scorch them all over previously to laying them down. When the magnitude of the superstructure requires that the solid earth should be pierced, piling is had recourse to; it consists in forcing into the infirm ground piles of squared fir, oak, or any other wood, usually about nine or ten inches square, of sufficient tenacity to withstand the driving, the required length being previously ascertained by boring the ground. The ends of the piles are commonly cased, or as it is called, shoed with pointed iron, and their upper ends or tops are cased with the same metal. The machine for forcing them consists of a frame of wood (the height of which must be regulated according to that of the pile and the power required in forcing it), framed and braced with broad and secure ledgers and feet: at the top is a cast-iron wheel usually about eighteen inches in diameter, the outer edge fluted to admit of a rope or chain to move in it, which rope or chain is attached to the axis of an iron cylindrical beater, which for ordinary purposes is from five to seven hundred lbs. in weight. This cylinder slides *sometimes* in grooves in the upright frame, and often on the face of the upright. There is also a ladder attached to the machine for the purpose of adjusting the chain in the wheel, and for oiling the machine: ten or even twenty or more men are employed, according to the nature of the soil through which the piles are to be driven, and they work the beater by raising it up and down in the frame, each taking the end of a rope for the purpose, which being all attached to the chain serve as so many handles. The labour is considered so hard, that it is not unusual, where a great many piles are to be driven, to employ double sets of men to work the beater alternately. Mr. Labelyn drove the piles of some of the foundations of Westminster Bridge by a machine worked by a horse. The machinery was considered intricate, and not practical for general purposes, and consequently it has been discontinued. The piles are usually driven as close together as they can be, and when finished their tops are sawn off and the intervals filled up,

up, by the Romans with coal, by us with chalk and rubble; and their tops are planked in the same manner as is described before for foundations in which planking only has been employed.

At the London docks the piles were all grooved on their opposite sides, and forced into the earth close together, and when all were so driven in, a tongue was forced down between each sufficiently strong to bind the whole together, and produce a continued chain of wooden piling connected from one end to the other of the foundation. Some architects have not deemed either planking or piling eligible for foundations in infirm or swampy ground, but have had recourse to a cradle, which consists of oak in quartering, and sometimes of fir, strongly framed and braced together in bays and in lengths of from five to ten feet, and of adequate width for the superstructure: these frames were again covered over by cross pieces or joists, and the whole was bedded firmly on the ground, and filled up flush by chalk or rubble work, for receiving the foundation of the brick or stone wall, and this has been found to answer perfectly well, and is safer than in trusting to planking only, because if the decay of the quarters of the cradle should take place, they being but partial, and the rubble still remaining united, a sinking of the building is avoided, which is of the greatest importance, and which is but too often the case in the practice by planking only.

In the foundations of bridges, the practice generally adopted by the ancients and moderns has been to lay the piers dry, either by turning the water into a new course, temporarily, or by the erection of a coffer-dam. A coffer-dam consists of a double chain of piles driven into the ground at a sufficient distance from the intended pier, to admit the work being conveniently proceeded in; when the piles are all firmly fixed in the earth, strong horizontal beams are framed and bolted to them with braces to stiffen the intermediate parts; they are finally planked inside and out, which forms a complete case, and the void between each casing is filled by fat mould or strong earth; thus secured, very little water is found to percolate, and this is removed by pumping. They have also practised another method somewhat more ingenious. The emperor Claudius practised it at the port of Ostia; Draguet Reys at the Mosque in the sea of Constantinople; Peronet at Pont Nieully, near Paris; and Sir Samuel Bentham at some works at Sheerness. It consisted of forming a strong grating of timber, covered with planks, which at once forms a floating raft, and the floor upon which the stone pier is to be erected; the pier is built upon the raft, and is composed of stones amply secured, and rendered by cement water-tight; the whole body is so arranged as to float upon the water until it has advanced in height; so that, if it were sunk, it should be above low-water-mark (if in a tidal river), or higher, as might be found expedient; this levity is obtained either by the assistance of vessels to which the raft is attached by ropes, or sometimes by the pier being worked up with sufficient vacuities to render it specifically lighter than an equal bulk of water; the pier is then sunk, either by letting the water into the vacuities, or by loosening the ropes (as the case may be), but it should be particularly observed previously to prepare the bed of the river to receive the intended pier.— This is done by machines of the description of ballast-heavers, and care should also be taken that the bottom of the masonry ground be level; should this not be the case, it must be raised either by pumping the water from out of the vacuities, or (if built in former manner) by means of machinery in the vessels; the operation is performed, in either case, till it ground to the satisfaction of the architect. Mr. Labelyn, in the erection of Westminster bridge, conceiving he had improved upon this latter method, erected the piers of it in caissons, or water-tight-boxes; the bulk of the box producing a mass, though loaded with the pier, specifically lighter than an equal bulk of water; after each pier had been erected, the sides of the box served again for boxes of other piers; the pier was sunk, and raised after the same manner as before described. Mr. Mylne, in erecting Blackfriars bridge, adopted the same method in regard to the caissons.

The practice adopted in the middle ages, as, at the bridges of Avignon, St. Esprit, Lyons, London, York, Newcastle, Rochester, &c., until modern times, was to drive piles into the bottom of the river, in the site of the intended pier, and then to cut them off a little below low water; the interstices were then filled with stone and strong cement: upon the piles they laid a grating of timber, boarded with thick boarding, which, so prepared, formed the floor to receive the intended pier; the workmen taking advantage of the times of low water, till the pier had risen to the level of high-water-mark. This manner is of the purest simplicity, nor does it require the aid of any machine beyond a pile-driving engine. The foundations of the piers of London bridge, as appeared from that which was removed, when the two small arches were converted into one, was composed of a quadruple row of piles driven in close together on the exterior site of the pier, forming a case to receive the stone and cement; it was not ascertained whether there were piles in the heart of the pier, for as soon as the exterior piles were taken out, the great force of the water cleared away the remainder, which were carried down the river. With a view to protect the piers of this bridge there have been constructed round them what are called starlings. A starling consists of an enclosure of piles driven into the bed of the river close together, and secured by horizontal pieces of timber, bolted by iron to the tops of the piles; and the void within, to the piling of the pier, is filled with chalk, gravel, stone, &c., so as to form a complete defence to the internal piling upon which the stone piers are erected.

It has been very improperly stated, that starlings are necessary to defend the piers in rivers liable to tidal currents, when constructed after the manner last described; on the contrary, the use of a starling is not to

defend piers of any particular construction, they have been used generally when by the plan of the bridge too little water-way has been left.

The walls of modern buildings are sometimes built for ornament, but more often in which both it and solidity are sought for. In London they are regulated by a specific Act of Parliament, but the act having been framed more as a protection from fire than as a security against dilapidation, a prudent builder finds it eligible to trust to the law to avoid inconvenience, but to strengthen his walls beyond the law to prevent their ruin. It is too much to ask for specifics in regard to the thickness of walls: they must be regulated, first, in reference to the nature of the materials to be employed; and, secondly, to the magnitude of the fabric to be erected. Walls of stone may be made one-fifth thinner than those of bricks; and brick walls, in the basement and ground stories of buildings of the first rate, should be reticulated with stone to prevent their splitting, a circumstance too much disregarded by our present builders.

A plinth in masonry is the first stone inserted above the ground; it is in one or more pieces, according to its situation, projecting beyond the wall above it about an inch; its projecting edge sloped downwards, or moulded, to carry off the water that may fall on it.

Ashlering is a term used by masons to designate the plain stone-work of the front of a building, in which all that is regarded is getting the stone (which is commonly no more than a casing to the wall) to a smooth face, called its plain-work. The courses should not be too high, and the joints should be crossed regularly, which will improve its appearance, and add to its solidity.

Fascia is a plain course of stone generally about one foot in height, projecting before the face of the ashlering about an inch, or in a line with the plinth of the building; it is fluted on its under edge (called by the workmen, throating), as a check to prevent the water from running over the ashlering; its upper edge is sloped downwards for the same purpose. It is commonly inserted above the windows of the ground stories, viz. between them and those of the principal story.

Cills.—These belong to the apertures of the doors and windows, at the bottom of which they are fixed; their thickness is various, most commonly about four inches and a half; they are also fluted on their under edges, and sunk on their upper sides, projecting somewhat beyond the ashlering, commonly about two inches.

Imposts.—These are insertions of stone with their front-facings commonly moulded, and sometimes left plain, and when so left they are prepared in a similar way to the fascias above described. They form the springing-stones to the arches in the apertures of a building, and are of the greatest utility.

Cornice.—This forms the crown to the ashlering at the summit of a building; it is frequently the part which is marked particularly by the architect to designate the particular order of his work, and when so, it is moulded to that character; hence there are cornices wrought after the three known orders in architecture, viz. the Doric, Ionic, and Corinthian, when perhaps no column of either is employed in the work, the cornice alone designating the particular style of the edifice. In working the cornice the mason should prepare the top or upper side, by splaying it away towards its front edge, that it may more readily convey off the water which may fall on it. At the joints of each of the stones of the cornice, throughout the whole length of the building, that part of each stone which comes nearest at the joints should be left projecting upwards a small way, called, by workmen, saddling the joints; the intention of which is to keep the rain-water from entering them, and washing out the cement; such joints, however, should be chased or indented, and such chases should be run full of lead. When dowels of iron are employed they should be fixed by melted lead also.

Blocking Course.—This is a course of stone traversing the top of the cornice, to which it is fixed, it is commonly in its height equal to the projection of the cornice. It is of great utility in giving support to the latter by its weight, and to which it adds grace. It at the same time admits of gutters being formed behind it to convey away the superfluous water from the covering of the building. The joints in it should always cross those of the cornice, and should be plugged with lead, or cramped on their upper edges with iron. The Romans sometimes dove-tailed the joints of such courses of stone.

Parapets.—These are of great ornament to the upper part of an edifice. They were used by the Greeks, and afterwards by the Romans, and are composed of three parts, viz. the plinth, which is the blocking course to the cornice; also, the shaft, or die, which is the part immediately above the plinth. It has a cornice, which is on its top, and projects in its mouldings sufficiently to carry off the rain-water from the shaft and plinth. In buildings of the Corinthian style the shaft of the parapet is perforated in the parts immediately over the apertures in the elevation, and balustrade enclosures are inserted in the perforations. The architects have devised the parapets with reference to the roof of the building which it is intended to obscure.

Pilasters.—In modern design these are frequently very capriciously applied. They are vertical shafts of square-edged stone, having but a small projection, with capitals and bases like columns; they are placed by us often on the face of the wall, and with a cornice over them. In Greek architecture they are to be met with commonly on the ends of the walls behind the columns, in which application their face was made double the width of their sides, their capitals differed materially from those of the columns which they accompanied, they were somewhat larger at bottom than at top, but without any entasis or swell. The best examples are to be found in Steuart's

Steuart's Ruins of Athens, viz. to the Propylea, temple of Minerva Polias, &c. &c.

Architraves adorn the apertures of a building, projecting somewhat from the face of the ashlering; they have their facing sunk with mouldings, and also their outside edges. When they traverse the curve of an arch they are called archivolts. They give beauty to the exterior of a building, and the best examples of them are to be found in the ancient Greek buildings, and in many also in Italy.

Rusticating, in architecture and masonry, consists in forming horizontal sinkings or grooves in the stone ashlering of an elevation, intersected by vertical or cross ones, perhaps invented to break the plainness of the wall, and to denote more obviously the crossing or bond of the stones. It is often formed by splaying away the edges of the stone only; in this style the groove forms the elbow of a geometrical square. Many architects omit the vertical grooves in rustics, so that their walls present an uniform series of horizontal sinkings. The French architects have been very fond of this method, as may be seen in the buildings at Paris; and the Bank of England is an instance of it in this country. There are abundance of ancient examples in each of the three manners.

Columns.—These comprise, generally, a conoidal shaft, with a small diminution upwards to their upper diameter, amounting generally to about one-sixth less than the lower diameter. They have sometimes a swell or entasis in their whole height (see Rules for making, article Architecture), but this practice was by no means general. The Greek ruins do not seem to countenance such a departure from nature, nevertheless it is found to have been commonly practised among the Roman buildings. The proportions of columns from the Egyptians to the Greeks have varied but little; the columns of the former, in their large temples, as at Thebes, amount to about four and a half diameters only in their height. The columns of the Parthenon, at Athens, are little more than five. In the best Roman examples they were increased to upwards of seven diameters. The columns of *all* the Grecian remains are fluted, and the fluting differs in each example. The Doric shafts have their flutes in very flat segments finished to an arris. To the other columns to the temples of Erectheus, Minerva Polias, &c. (both of the Ionic style), flutings of the semi-ellipsis shape with fillets were adapted.

The application of columns has been that in which the architect has most endeavoured to display his genius. The Greeks surrounded their public works with them; their porticos carried this kind of splendour to its highest, as in them may be sought and found the whole syntax of architecture and masonry. To construct a temple in the Greek manner required a consummate knowledge of architecture, combined with an exquisite taste united to great judgment. In the Parthenon, at Athens, is to be found the most elaborate display of masonry in the world. This temple to Minerva is the best example of this important branch (see Plate I., *Fig.* 4). The columns are all constructed of single blocks in diameter, and in courses of more than a diameter in height (BB, *Fig. a*). The wall enclosing the cell of the temple (*Fig.* 4), is formed of a single course of marble blocks, in thickness, shewing a face inside and outside, the vertical joints corresponding over each other, and in seventeen horizontal courses, reckoning from the bottom of the architrave to the top of the upper step, and rising to an height of thirty-three feet. The capitals to the columns consist each of one single block, two feet nine inches high, and the architrave lies upon them. The architraves are composed of three blocks in thickness from face to back, each in length extending from centre to centre of the columns, and above fourteen feet long each, and that over the central intercolumniation is seventeen feet, and each block also the whole height of the architrave, and of an equal thickness. The frieze is in two regular courses in height, and each course wants so much of being the whole thickness of the frieze as allows the metope to lie against it. The triglyph tails are (AA, *Fig.* 2) in one height, but does not go through it, and was so formed that the back of the block was considerably narrower where it went into the frieze than the breadth of the triglyph, so that each side of the triglyph projected on to the face of the slab of the metope (BB, *Fig.* 2) several inches, thus forming a rebate which enclosed the metope; and which completely prevented their removal without taking off the cornice and pediment, and gave strength and solidity to the whole sculptures of the friezes. The cornice is in blocks, which are the width of one mutule and one of the spaces between them (Elevation, *Fig.* 1), their ends forming a complete course on the inside. The tympanum of the pediment is composed of one course of upright slabs on the outside face, with horizontal courses behind them. The pavement of the temple is in squares of equal size, of about five feet each, and about one foot in thickness (two or three of which are amongst Lord Elgin's Athenian marbles), joined with the most mathematical precision.

The perfect state in which the monuments of Greece still remain, which have not been destroyed by violence, is a proof of the great judgment with which they were constructed. The famous temple to Minerva would have been entire at this day if a bomb had not been thrown into it by the Venetians, when it was used as the powder magazine of the Turks. The Propylea, applied to the same purpose, was struck by lightning, and blown up. The temple of Theseus, not having been exposed to accidents of this nature, is almost as entire as when first erected. The little choragic monument of Thrasyllus, as well as that of Lysicrates, are also entire. These are sufficient instances to shew the great judgment employed by the Athenians in the construction of their buildings, and it is hoped to impress on modern architects and masons the utility of employing large blocks, and also of causing great accuracy in joining

joining them together, without which masonry is not better than bricklaying. The core of rubble work now remaining in many of their walls is impenetrable to a tool, an additional proof if any be wanting of the care employed in cementing the masonry.

The mode of erecting columns into screens or porticos remains to be treated on. The Doric column was effected in Greece without a base, it having a large diameter which compounded for this deficiency. This column was invariably approached by three steps, (see *Fig.* 4. *c c c*) the third or last forming the floor on which it was built. The lower shafts, as well as the intended intercolumniation, were accurately marked out on the floor, and on the parts to which the columns were designed to be placed. A circle was drawn about $\frac{2}{15}$th of the diameter of that of the column, which was sunk down (See Plate I. *Fig.* 3. D D.). The lower shaft was accurately shaped at its lowest extremity to the proposed diameter (A, *Fig.* 3), leaving it so much longer as to fit into the sinking in the upper step, which formed for it a kind of rebate, by thus fixing all the shafts in the floor their intercolumniations were exactly preserved. The column is composed of blocks (BB, *Fig.* 4), of, at least, a diameter in height, exactly jointed, and, by the Greeks, without the *least* cement between them. In the centre of each joint were made square sinkings for the purpose of putting in a joggle; this joggle enters both the upper and lower shafts, and serves to prevent the moving or fracture of the column by any lateral thrust it might receive. The joggles in the columns of the Parthenon were of olive-wood; they are commonly with us of iron painted over, or of lead; and, in columns of marble, they are copper. The latter metal being preferred by reason of its not being so liable to oxydate as the former, and consequently not so probable to stain the stone, which is too often the case by iron joggling.

The joining of columns in free-stone has been found more difficult than in marble, and the French masons have a practice to avoid the failure of the two arrisses of the joint, which might be borrowed with success for the constructing of columns of some of our softer free-stones. It consists in sinking away the edge of the joints, by which means a groove is formed at every one, throughout the whole height of the column. Travellers who have seen their porticos have compared them to cheeses piled one on the other, the courses appearing, by this practice, to be so regularly marked. This method is not had recourse to but for plain shafts: it is not altogether of modern invention, as there are some ancient remains in which it appears, but in them it may be conjectured to have been for a very different purpose. It served to admit the shafts being adorned by flowers and other insignia on the occasion of their shews and games. In the French capital they even now, on their public illuminations, affix rows of lamps on their columns, making use of these grooves to adjust them regularly, which produces a very good effect.

The shafts of columns in large works intended to be adorned by flutes, are erected plain, and the fluting chiselled out afterwards. The ancients commonly formed the two extreme ends of the fluting previously, as may be seen in the remaining columns of the temple of Apollo, in the island of Delos, a practice admitting of great accuracy and neatness. The finishing the detail of both sculpture and masonry on the building itself was a universal practice among the ancients: they raised their columns first in rough blocks, on them the architraves and friezes, and surmounted the whole by the cornice, finishing such parts only down as were not conveniently to be got at in the building; hence, perhaps, in some measure, arose that striking proportion of parts together with the beautiful curvature and finish given to all the profiles in Grecian buildings.

The Greeks, who carried architecture to its highest, seem by their skill to have even chained down the public convenience to submit to her notions of sublimity. Thus we find, that the general basement of the Parthenon is composed of three gradations, or steps, (*Plate* I. *Fig.* 4, *c c c*) not proportioned to the human step, but to the diameter of the columns it supports, and forms one single feature extending through the length of the temple, and of strength and consequence sufficient to give stability and breadth to the mass above it. The same means were pursued in all their works, viz. in those of the Ionic and Corinthian styles, for the Greeks affected none other. The bases and capitals to the columns, and also the antæ, were executed on the building, as well as the accessories or ornamented parts; and although this practice is not common among us, our neighbours, the French, who certainly are much our *superiors* in architecture, always adopt it. It has one great public convenience (besides admitting greater accuracy in finishing) by allowing of more rapidity in carrying forward the work, blocks being inserted for and instead of laboured bases and capitals, from which circumstances the case of the building is sooner ready to receive its roof, and the interior may be more quickly prepared for its intended purpose than by waiting for all the several parts to be previously wrought and finished to be inserted in the progress of the work; hence the public convenience becomes sooner supplied, and if the finances should fail of fully effecting the whole intention of the design, such failure would only effect the ornamental part; enough will remain to exhibit the genius of the architect, and the work may be completed, if it be worthy, in more prosperous circumstances. The French people seem fully to have fallen in with this idea, for they have frequently left unfinished the decorative part of their edifices, as there are now to be seen at Paris and other places whole ranges of columns and pilasters with no indication of their precise order, except what may be collected from the shape and size of the blocks inserted in the walls to form them.

Pavements have occupied considerable attention in architecture, and consequently masonry. The Greek temples were paved with white marble, the same as that

that of which the temple itself was constructed; and consisted of large squares joined with great precision, and of such thickness as secured their stability; the remaining stones in the Propylea, at Athens, are fifteen inches in thickness; and those in the Minerva temple, eighteen inches. The Turks have found the greatest difficulty in removing them, as has been their practice, for the purpose of making lime for their present houses.

Tessellated Mosaic pavements were used by the Athenians, and consisted in forming, by inlaying marble in various specimens, to exhibit the most agreeable and fanciful designs. Mr. Steuart discovered a fragment of one, of great beauty, in the Ionic temple on the Ilissus, at Athens. In the disclosures at Pompeii many floors were found to be so paved. There does not, however, appear in Greece such marks of luxury and extravagance in the decorative parts of their buildings as the opulent Romans displayed, who, not content with inserting in their floors pieces of marble of the most beautiful kind, had them painted and varied with different colours. This custom commenced under Claudius. Under Nero they began to cover the marble with gold, thus the marble of Numidia was gilded, and that of Phrygia was stained with purple.

The mode of staining marble was so perfect that the dyers of Lacedemon and Tyre were envious of the purple lustre which their marbles exhibited. Pieces of solid gold, called crassum aurum, and of the same metal beaten out called "bracteæ," were inlaid. Some women, says Seneca, "had baths paved with pure silver; they placed their feet on the same kind of metal in which their food was served up." Such and other traits of splendour are mentioned in the description which Statius gives of the country-house of Manlius Vopiscus.

Arching is that in which the modern mason has exceedingly excelled the ancient. In Greece, if it were understood, it was but little practised; but there, as in Egypt, the necessity of it was not so imperious as it was afterwards in Italy, and latterly in Europe; the former countries abounded in quarries of marble, from which they could collect pieces of sufficient dimension to compose lintels for all their apertures, and also for the roofs of their porticos, which were formed of marble; and they appear satisfied in this application, without having had recourse to arching, which they must, had not their marble been adequate to the support of great weights laying in horizontal positions. The Romans, who were indebted to the Greeks for all that they performed on scientific principles in architecture, took the rules that were afforded in arching (although scanty) by their teachers, and if they did not much improve them, made them more common; hence we find, in most of the Roman edifices arches in all positions, in some of which there is great boldness of design, as well as intelligence displayed; but, as is usual in the infancy of an invention, they appear never to have carried them above, or varied them from, the portion of a circle altering its versed sign only to answer the numerous purposes of strength and ornament in building.—The ancient Roman architects seem not to have been conducted, in these their principles of arcuation, by certain and geometrical principles, experience and imitation served them principally as guides. The circle with them answered every purpose; and experience having shewn its utility, no one seems to have pressed from the ranks to exhibit his enterprise by a deviation; this was left for the work of the moderns, and, like the late developements in chemistry, to which it nearly approaches in both genius and importance, may, in its results, eventually connect the most distant by the easiest possible means, as well as promote the convenience of the present and admiration of succeeding ages.

The masonry of an arch herein to be treated of, is so intimately connected with the theory, that it appears almost impossible to explain the one without giving some information respecting the other. In theory, an arch may be explained as follows, viz. to consist of series of stones, called voissoirs, in the shape of truncated wedges which resist each other, through their inclined sides, by means of that weight whereby they would otherwise fall, and are suspended in the air without any support from below, where a concavity is formed. The voissoirs are subject to forces which arise from their own weight, from external pressure, from friction, and the cohesion of matter; all these forces compose a system which ought to be in equilibration; and, moreover, that state ought to have a consistence firm and durable. It was not till near the end of the seventeenth century when the Newtonian mathematics opened the road to true mechanical science, that the mathematicians directed any part of their attention to the theory of arches. Dr. Hook gave the first hint of a principle, when he affirmed, that the figure into which a chain or rope, perfectly flexible, will arrange itself, when suspended from two hooks, becomes, when inverted, the proper form for an arch constituted of stones of uniform weight and size. The reason on which he grounded his assertion, is, simply, that the forces with which the parts of a standing arch press mutually on each other, in the latter case, are precisely equal and opposite to those with which they pull each other in the case of suspension. This principle, true as far as it goes, gave rise to most of the specious theories of the mathematicians; for they did not consider that though an arch of equal voissoirs might be thus balanced, it would require much other matter to be placed over it, to fill up the space between the extrados and a roadway, if used for the purpose of a bridge, and that this superincumbent mass must necessarily destroy the equilibrium previously existing in the unloaded arch. There is a certain thickness in the crown which will put the catenaria in equilibrio, even with a horizontal roadway; but this thickness is so great that the pressure at the vertex is equal to the horizontal thrust: the only situation,

tuation, therefore, in which the catenarian would be proper, is in an arcade, carrying a height of dead wall above it. During these discussions on the celebrated catenaria, a new system of arching developed itself. It was deduced from the consideration of the arch-stones being frustrums, or parts of wedges; hence the mathematical properties of the wedge were introduced into the science, and employed to establish the theory of what were called balanced arches; this practice was taught in France by La Hire, Parent, Varignon, Belidor, Riou, &c., and some bridges were formed on its principles, viz. Pont La Concorde, at Paris, and also one arch at Nieully. It required that the arch-stones should be as long as economy would admit, and, if possible, to fill up all the space between the intrados and extrados of the bridge; and further, they are all to be locked together by bars and wedges of iron, which will prevent the possibility of their sliding, on the arch quitting the centering; a circumstance not before accomplished in arching.

The theorist not yet having brought the practical architect to adopt his visions, raised another system, which is said to secure a perfectly equilibrated structure, by making an equality at every point of the curve. The deduction from this theory consists in making the height of the wall incumbent on any point of the intrados, directly as the cube of the secant of the curve's inclination to the horizon at that point, or inversely as the radius of curvature there. It must be added, that this theory expects the joints of the voissoirs to be perfectly smooth, and not to be connected by any cement, and therefore to sustain each other merely by the equilibrium of their vertical pressure; and the theorist says, "an arch which thus sustains itself, must be stronger than another which would not, because when in imagination we suppose both to acquire connexion by cement, the first preserves the influence of this connexion unimpaired; whereas in the other, part of the cohesion is wasted in counteracting the tendency of some parts to break off from the rest by want of equilibrium. From these systems have been made tables for forming arches to equilibrate, by which the nature of each voissoir may be found to any degree of curvation, and Dr. Hutton has simplified it for practical men—(see Table, article Arch, Part I, page 341). The practical mason, however neat in the execution of his work, finds it extremely difficult to get the joints of the arch-stones so smooth as is required by these systems; and even if he succeeds in doing so, circumstances may take place in the construction of the work to render it useless; for instance, the abutments may sink a little, and one may retire more than another, hence will arise an alteration in the arch, and, consequently, in the shape of the joints; but there are other circumstances to be anticipated, known to the practical architect (if even a sinking of the abutments should not take place), which is an alteration in the centre on which the masonry is raised. It is ascertained, that however firmly it may be constructed and supported, its curvature will vary as it receives the weight of the stone arch. It not being possible that the centre could be loaded all at once, produces this variation; but even if the centre should be so constructed as to remain firm and unalterable, a sinking will ensue on its removal; this, as the practice is, is done gradually, and all the arch-stones in some measure follow it; the middle ones squeezing the lateral ones aside, which compresses all between them; hence the latter arch stones alter their shape, a sinking of the crown ensues, consequently a general change of form of not only the joints, but of the arch also. Some architects, to secure as little friction in the joints as possible, have covered their surfaces with sheet-lead, and this practice was followed in the bridge of Blackfriars, at Norwich, by Mr. Soane. It cannot be too strongly recommended to the mason concerned in arching, to make all the joints meet as correctly as possible, using the least possible quantity of cement between them: the practice of wedging in the voissoirs at the crown of the arch, commonly practised, should be done with caution, or, instead of preventing a sinking, it may endanger the whole arch. Peronet, who was architect to so many bridges in France, and whose experience and sagacity in this branch of practice, had developed more than a whole magazine of theorists could do, rejected it. His rejection of it was not however to the principle, but to the uncertainty in the persons employed to perform it; he conceived that the stones might be so fractured in forcing them in, that no two flat surfaces would present themselves in that part of the arch.—Nieully, one of the finest bridges he built, and which the writer of this article has repeatedly examined, is of a very superior construction; the road occasions very little elevation, no more than sufficient to keep it dry. The arches and piers are quite unique in their shape, of considerable span, and so apparently flat and thin in the crown, as at first sight to create a doubt if they be of stone. It is a principle in the French bridges that the passengers may see their roadway from one end to the other. It would *not be* endured by them to be ascending mountains over the inland waters; and if their bridges are not so strong as ours, they exhibit more intelligence, convenience, and beauty.

The figures of arches are as various in their shape as the most fastidious ideas of convenience can require; they were, in the bridges of the Romans, semi-circles; by the moderns, of every form and curvature fancy can suggest, or geometry delineate; but the practical mason should endeavour in effecting arches, if he expects the praise of intelligent men, to protect them by some reference to known principles. Every arch of curvature (and it cannot be an arch without it, although it may be a lintel), should be described by its praxis in known geometry, and if it require one, two, or more centres to develope its form, the workman should not forget that these points once ascertained are his guides to find the shape of the voissoirs or arch-stones. The joints of an arch are all traced from the centres of their curvature,

curvature, so that as a general axiom it may be assumed, for instance, speaking of a semi-circle, that its centre supplies the principle of giving form to the voissoirs; if a segment, the centre of the circle of which it is the segment, be its versed sign what it may. If an ellipsis, which is neither more nor less than three segments, the arch-joints must be drawn from the centres of each correspondent circle, and so on to the parabola, hyperbola, &c.: if these principles were attended to by the practical mason, the failure of so many arches in the smaller works would be prevented, and the arch itself appear more neat; inasmuch as principle would be opposed to that which is most commonly done by chance, as may be seen by any attentive observer, on looking at the arches in some of our buildings.

Of Domes.—A dome is said to be less difficult of construction than an arch, by reason that the tendency of each part to fall is counteracted not only by the pressure of the parts above and below, but also by the resistance of those which are situated on each side. A dome may therefore be erected without any temporary support, like the centre which is required for the construction of an arch, and it may at last be left open at the summit, without standing in need of a key-stone.

The Greeks seem no more to have employed domes than they did arches, one * only having been preserved, and in that there is nothing to require any of the principles of the Tambour-wall, as it is composed of a single piece. The Romans certainly affected domes, in which they developed great enterprise, genius and taste. Vitruvius says nothing about them, though he gives proportions for his monoptereal buildings, as, probably, they were but little employed in his time; but we have still existing the Pantheon of Agrippa, over which there is a beautiful hemispherical roof, and it is probable that all their round temples were so roofed; indeed, in the remains of the Sybils' temple at *Tivoli*, there are evident marks of such a covering.

The masonry of domes must be conducted on similar principles to those recommended for arching, excepting only that the figure of each voissoir or wedge will be so shaped as to fit the void in a sphere instead of its sections. The weight of masonry in a dome, however, will require all the force of mind in the architect and mason to prevent its forcing out its lower parts; for instance, if it rises in a direction too nearly vertical, with its form spherical, and its thickness equable, it will require to be confined by a chain or hoop, as soon as the rise reaches to about $\frac{1}{14}$ths of the whole diameter; but if the precaution be taken of diminishing the thickness of the masonry as it rises, it will not require to be so bound.

The dome of the Pantheon is nearly circular, and its lower parts are so much thicker than its upper parts as to afford sufficient resistance to their pressure, and this was further prevented from spreading by being furnished with many projections which answer the purpose of abutments and buttresses.

* The monument of Lysicrates, at Athens.

At the restoration of the Arts in Italy, in the fifteenth century, the architects, no doubt struck with the amazing effect of domes, from viewing that remaining to the Pantheon, projected many to the cathedrals and other edifices at that time undertaken; but their skill was not equal to their zeal, and many attempts from want of the former, failed.

At Constantinople, the church of St. Sophia was covered by a dome, and its history will be useful to prevent the temerity of the unscientific. Anthemius and Isidorus, whom the emperor Justinian had selected as architects the most proper for conducting the works of this celebrated edifice, seem to have known but little of the matter. Anthemius had boasted to Justinian that he would outdo the magnificence of the Roman Pantheon, for he would hang a greater dome than it aloft in the air; accordingly he attempted to raise it on the heads of four piers, distant from each other about one hundred and fifteen feet, and about the same height. He had probably seen the magnificent vaultings of the temple of Mars the Avenger, and also of the temple of Peace, at Rome, the thrusts of the vaultings of which were withstood by two masses of solid wall which joined the side walls of the temple at right angles, and extended sidewise to a great distance. It was evident that the walls of this temple could not yield to the pressure of the vaulting, without pushing these immense buttresses along their foundations; he therefore in imitation placed four buttresses to aid his piers. They are almost solid masses of stone, extending at least ninety feet from the piers to the north and to the south, forming, as it were, the side walls of the cross. They effectually secured them from the thrusts of the two great arches of the nave which supported the dome; but there was no such provision against the thrust of the great north and south arches. Anthemius trusted for this to the half dome which covered the semi-circular east end of the church, and which occupied the whole eastern arch of the great dome: but when the dome was finished, and had stood a few months, it pushed the two eastern piers, with their buttresses, from the perpendicular, making them lean to the eastward, and the dome and half dome fell in. Isidorus, who succeeded to the work on the death of Anthemius, strengthened the piers on the east side, by filling up some hollows, and again raised the dome, but things gave way before it was finished; and while they were building in one part it was falling in another. The pillars and walls of the eastern semi-circular end were much shattered by this time. Isidorus, seeing they could give no resistance to the push which was so evidently directed that way, erected some clumsy buttresses on the east wall of the square which surrounded the whole Greek-cross, and these were roofed in with it, forming a sort of cloister, and leaning against the piers of the dome, and thus opposed the thrusts of the great north and south arches. The dome was now turned for the third time, and many contrivances were adopted for making it extremely light. It was made offensively flat, and, except the ribs, it was roofed with pumice-

pumice-stone; but, notwithstanding these precautions, the arches settled so as to alarm the architects, and they made all sure by filling up the whole from top to bottom with arcades in three stories. The lowest arcade was very lofty, supported by four noble marble columns, and thus preserved, in some measure, the church in the form of a Greek-cross. The story above formed a gallery for the women, and had six columns in front, so that they did not bear fairly on those below. The third story was a dead wall, filling up the arch, and pierced with three rows of small ill-shaped windows: in this unworkmanlike shape it has stood till now, and is the oldest church in the world, but it is an ugly misshapen mass of deformity and ignorance, resembling any thing rather than what it was intended for, viz. a beautiful piece of architecture.

But there has been domes effected since in every part of Europe, combining and displaying, in this species of building, every requisite of beauty and strength. The one to St. Peter's, at Rome, is a superb undertaking; and the set-off to it in this country, of St. Paul's, is another, in which equal talent is developed; but this latter dome is more remarkable for its carpentry than its masonry. At Paris they have that to the church of the Invalids, a beautiful work; and one, of very recent construction, to St. Genevieve, now called the Pantheon; on the frieze of the portico of which is the following inscription in bronze letters, *Aux grand hommes la Patrie connoisante.* This latter dome, including the peristyle on which it rests, is perhaps the most beautiful in form and composition in existence. The peristyle is formed by fifty-two columns of the Corinthian order, completely insulated, and standing on a circular stylobate, each above fifty feet high. The dome rises above the cornice of the peristyle in a beautiful curved line, and, on its top, is formed a pedestal and gallery. On the pedestal is erected a bronze statue of the figure of Fame, twenty-eight feet high: but here, as in St. Sophia, the work of dilapidation has commenced. It was observed, after the dome was raised, that the columns composing the interior began to sink with the weight. This interior consisted of four naves, over the centre of which was the lantern and dome; they are decorated with one hundred and thirty fluted columns of the Corinthian order, twenty-eight feet high, completely insulated; the shafts of some of which began to fracture at their joinings, which obviously arose from the inadequacy of the material they were composed of, and, to remove this defect, the architects have directed the walling up of the intercolumniation at the four quarters of the screen, in order to prevent its further giving way; and this now having been done, a monument at once of great genius and taste may be preserved.

A dome has been erected to the rotundo of the Bank of England, in which the principles of the ancient one of the Pantheon, at Rome, has been followed. It takes its spring from a wall of great thickness, on which it is bedded, furnished by many projections externally graduated like steps, which answer the purpose of buttresses. It is open at its summit, like that from which it is copied, and from which the interior of the building receives its light. It composes, on the whole, a structure unique, and very honourable to the talents of the architect, Mr. Soane.

The masonry of Gothic architecture now remains to be treated. It is pretty generally agreed among antiquaries, that we had few, if any, buildings of stone previous to the Norman advent: indeed, it is observed, "that before that event most of our monasteries and church buildings were of wood." "All the monasteries of my realm," saith king Edgar, in his charter to the abbey of Malmesbury, dated in the year 974, "to the sight are nothing but worm-eaten and rotten timber and boards:" and that upon the Norman conquest such timber fabrics grew out of use, and gave place to stone buildings, raised upon arches; a form of structure introduced by that nation, furnished with stone from Caen, in Normandy.

"In the year 1087 (Stow's words of the cathedral of London) this church of St. Paul was burnt with fire, and therewith most part of the city: Mauritius, then bishop, began therefore the new foundation of a new church of St. Paul; a work that men of that time judged would never have been finished, it was to them so wonderful for length and breadth, as also the same was builded upon arches of stone, for defence of fire; which was a manner of work before that time unknown to the people of this nation, and then brought from the French, and the stone was fetched from Caen, in Normandy." St. Mary le Bow church, in London, being built much about the same time, and manner, that is, on arches of stone, was therefore called New Mary church, or St. Mary le Bow; as Stratford bridge, being the first builded with arches of stone, was therefore called Stratford le Bow. This, doubtless, is that new kind of architecture the continuer of Bede intends, where speaking of the Normans, he saith, "you may observe every where in villages, churches; and in cities and villages, monasteries erected with a new kind of architecture." And again, speaking doubtfully of the age of the eastern part of the choir of Canterbury, he adds, "I dare constantly and confidently deny it to be elder than the Norman conquest, because of the building it upon arches, a form of architecture, though in use with, and among the Romans long before, yet, after their departure, not used here in England till the Normans brought it over with them from France."

It is barely probable that we should have continued ignorant of masonry till this period, and that we did not there is abundant proof. With regard to the churches being of wood, the only authority produced for it, is the expression in one of king Edgar's charters concerning the ruinous state of the monasteries in his time. It is true, indeed, some of their fabrics seem to have been totally formed of timber. Bede, in his Ecclesiastical History, mentions a chapel so built on occasion of the conversion of Edwin, king of Northumberland, for the

purpose

purpose of his baptism. But he likewise informs us, that soon after the king was baptized, he laid the foundation of a stately and magnificent fabric of stone: this king was baptized in the year 627, several hundred years previously to the reign of the Norman king; so that there is a great probability that the art of constructing buildings of strength, supported by arches and vaulting, was well understood long before. Among the fabrics of these times may be included many heathen temples, some of which were built by the Saxons themselves. In what these temples differed from the Christian churches may be difficult to determine with any certainty; pope Gregory, however, advised Augustin not to demolish them, but only that the idols that were in them should be removed and destroyed, and then consecrated to the service of the true God. As the work of conversion was at this time going on rapidly, a zeal began to display itself in erecting churches and other places of worship. One of the first erected Saxon churches of any consequence appears to have been at Canterbury, and Bede says, "it was called St. Peter, and in which all the bodies of the bishops of Canterbury were interred." From this time to the conquest, and for some time after, Saxon architecture was the prevailing taste of the nation, and many edifices combining all the requisites of true building were made. The characteristic marks of this style are these:—The walls were very thick, generally without *buttresses*; the arches, both within and without, as well as those over the doors and windows, semi-circular, and supported by very solid or rather clumsy columns, with a kind of regular base and capital. In short, plainness and solidity constitute the striking features of this method of building: nevertheless, the architects of those days sometimes deviated from this rule, their capitals were adorned with carvings of foliage, and even animals; and their massive columns were decorated with small half-columns united to them, and their surfaces ornamented with spirals, squares, lozenges, network, and other figures, either engraven or in relievo; various instances of these may be seen in the cathedral of Canterbury, the monastery at Landisfern, the cathedral at Durham, and the ruined choir at Orford, in Suffolk. Their arches too, though generally plain, sometimes came in for more than their share of ornaments; particularly those over the chief doors, some of these were overloaded with a profusion of carving. Bishop Warburton, in his notes on Pope's Epistles, says, "all our ancient churches are called, without distinction, Gothic, but erroneously. They are of two sorts; the one built in the Saxon times, the other in the Norman." Several cathedral and collegiate churches of the first sort are yet remaining, either in whole or in part; of which, says he, this was the original. When the Saxon kings became Christians, their piety (which was the piety of the times) consisted chiefly in building churches at home, or performing pilgrimages abroad, especially to the Holy Land; and these spiritual exercises assisted and supported one another. For the most venerable, as well as most elegant models of religious edifices were then in Palestine. From these the Saxon builders took the whole of their ideas, as may be seen by comparing the drawings which travellers have given us of the churches still standing in that country, with the Saxon remains of what we find at home. Now the architecture of the Holy Land was Grecian, or rather Roman, but greatly fallen from its ancient elegance. Our Saxon performance was indeed a bad copy of it, yet still the footsteps of the ancient art appeared in the circular arches, the entire columns, the division of the entablature into a sort of architrave, frieze and cornice, and a solidity equally diffused over the whole mass.

To the Saxon style of building succeeded the Norman, or pointed style. The marks which constitute its character are its numerous and prominent buttresses, its lofty spires and pinnacles, its large and ramified windows, its ornamental niches or canopies, its sculptured saints, the delicate lace-work of its fretted roofs, and the profusion of ornaments lavished indiscriminately over the whole building; but its peculiar distinguishing characteristics are, the small clustered pillars and pointed arches formed by the segments of two intersected circles, which arches, though last brought into use, are of more simple construction than the semi-circular ones. Sir C. Wren, who, in his Parentalia, has considered this style of building, refers it to Saracen origin. He says, "the Holy war gave the Christians who had been there an idea of the Saracen works, which were afterwards by them imitated in the west, and they refined upon it every day as they proceeded in building churches. The Italians (among whom were yet some Greek refugees), and with them French, Germans, and Flemings, joined into a fraternity of architects, procured papal bulls for their encouragement and particular privileges. They styled themselves Free-masons, and ranged from one nation to another as they found churches to be built (for very many in those ages were every where building, through piety or emulation); their government was regular, and where they fixed, near the building in hand, they made a camp of huts. A surveyor governed in chief; every tenth man was called a warden, and overlooked each nine: the gentlemen of the neighbourhood, either out of charity, or commutation of penance, gave the materials and carriage." He proceeds, "those who have seen the exact accounts in records of the charge of the fabrics of some of our cathedrals, near four hundred years old, cannot but have a great esteem for their economy, and admire how soon they erected such lofty structures. Indeed, great height they thought the greatest magnificence. Few stones were used but what a man might carry up a ladder on his back from scaffold to scaffold, though they had pulleys and spoked wheels upon occasions; but having rejected cornices, they had no need of great engines, stone upon stone was easily piled up to great heights, therefore the pride of their works was in pinnacles and steeples."

The difficulty of tracing the origin of the buildings with pointed arches, in this country, in some measure vanishes by a close inspection, for towards the latter end of

of Henry the Second's reign some pointed arches appear, and also the columns are more slender, supporting archivolts of a different style, but they do not appear to have wholly prevailed during this reign, as some short solid columns and semi-circular arches are retained, and mixed with the pointed ones. An example of this is seen in the west end of the Old Temple church, and at York, where under the choir remains much of the ancient work, the arches of which are but just pointed and rise on short round pillars: both these were built in that reign.

In the reign of the third Henry, the pointed style seems to have gained a complete footing. Indeed like all novelties when once admitted, the rage of fashion made it become so prevalent, that many of the ancient and solid buildings erected in previous reigns were taken down in order to be re-edified in the new taste, or had additions made to them in this mode of architecture. The cathedral church of Salisbury was begun early in this reign and finished in 1253. It is entirely in the pointed style, and is considered the best pattern of that age. Its excellency is undoubtedly in a great measure owing to its being constructed on one plan, whence has arisen a symmetry and proportion of parts not to be met with in many of our other cathedral churches.

In Edward the First and Second's reign no very material alteration appears to have been made, except perhaps towards the end of the latter king's reign the vaulting of the roofs became more decorated than before; for now the principal ribs being spread over the inner face of the arch run into an assemblage of tracery, dividing the roof into various angular compartments, and were usually ornamented at their intersections with orbs gilded, heads of figures, and other embossed work. The columns consisted of an assemblage of small pillars or shafts, not detached or separate from the body of the column, but made a part of it. The windows were also greatly enlarged and divided into several compartments by stone mullions branching off at the top into various ramifications, and more particularly so, those to the Eastern and Western ends of the buildings, which were large, often taking up nearly the whole breadth of the nave and as high almost as the vaulting, set off by numerous details of beautifully painted glass representing kings, saints, martyrs, and confessors. Ely cathedral furnishes abundant specimens of the style of the first and second Edwards. The same style afterwards began to prevail all over the kingdom, and continued improving through every successive reign to its final decline in Henry the Eighth's, and its total overthrow in Edward the Sixth's and Elizabeth's time. In Henry the Seventh's time this species of building arrived at a perfection surpassing every thing that had before been seen. Every detail of the sculpture and masonry was better executed; a taste for statuary began to appear; the ribs and vaulting of the roofs, which had been before large and seemingly formed for strength and support became now divided, and as from a centre spreading themselves over the vaulting, which gave the whole the appearance of embroidery with clusters of pendant ornaments hanging down from the roofs. The most striking instance of this kind is, the chapel of King Henry the Seventh at Westminster, King's College Chapel at Cambridge is another instance of the superlative style of architecture of these reigns. This magnificent edifice had its principal ornaments during Henry the Eighth's reign. The towers were finished, as well as most of its spreading roofs and tracery work; some curious documents still existing in the archives of the college shew the contracts of the artificers employed, and exhibit a singular contrast to modern valuations. In one contract is set forth the following items, concerning the erecting of the "fynyals" or pinnacles for twenty-one buttresses, and finishing one of the towers, one "fynyal" having been previously set up as a pattern. The contract runs thus, "for every pinacle to be paid 6l. 13s. 4d.; and for all the said pinnacles £100, and for the upper part of the tower (viz. from the open-work upwards) £100; the provost, &c. to find iron-work to the amount of £5 for each pinnacle. In this reign bricks became much in use, the arches were flatter than in the time of the Edwards. The exquisite tracery adorning the roofs and vaulting made this kind of arch necessary, in order to bring the work of the sculptor nearer the spectator's eye. In all Cardinal Wolsey's buildings is to be seen this low-pointed arch. It was described from four centres, was very round at the haunches, and the angle at the top was very obtuse. There is now a generally prevailing opinion among antiquaries, that this style of architecture took its rise and received its culture in this kingdom, arising partly from the numerous remains still extant; in which they fancy they can trace all its various improvements until it arrives at its greatest perfection and glory. From this understanding and concurrence among professional men, they have now in their writings discarded the term Gothic, as applied to the manner of building from the thirteenth to the sixteenth century, and have substituted the word English; and for the style which subsisted previously to the former period, and was introduced at the conquest, and whose chief characteristic and feature is an highly-pointed arch, they call Norman; and to all buildings before the conquest they apply the term Saxon. The architecture used by the Saxons is very properly called Saxon. The improvements introduced after the Norman conquest justify the application of Norman to the edifices of that period.

The nation assumed a new character about the time of Henry the Second. The language properly called English was then formed, and an architecture founded on the Norman and Saxon, but extremely different from both, was invented, cherished, and employed by the English; this is now called the English style. The term Gothic certainly has no real application to the architecture for which it is applied to distinguish; these people, (viz. the Goths and Vandals) had ceased to make any figure in the world long before this species of building was in use. Sir C. Wren is the first English

English writer who has applied it to designate this species of architecture, who most probably adopted it from the Italians of the fifteenth century, who were in the habit of applying it to all the buildings not done after the fashion of the remains then existing in Italy. The term "La Maniera Gotica" was used, partly no doubt in contempt and partly to distinguish such works from what was considered by them the legitimate style of architecture. This digression on the architecture of these islands, was deemed eligible and necessary, as it would have been absurd to treat of their masonry without some notices of the buildings to which it had been applied.

The desideratum of skill in all these works in which the division of stone has produced the most striking effects is in the arching and vaulting. The other masonry was performed in the usual manner, adopting the means to the local advantages derivable from the nature of the material to be employed. The process of working in freestone was the mason's chief employ; this they did with considerable address and judgment: they made the walls of great thickness, composed of many small stones accurately wrought and blended together and with great compactness. The height of those walls, together with the long and highly-pointed windows covered by a vaulted cieling, made it necessary to erect buttresses; these prevented the long narrow piers between the windows from splitting, and secured the side-walls from the thrust of the ribs and arches of the vaultings. The pinnacles which crowned the buttresses, and which were carried considerably above the parapets of the roofs, added by their weight to the solidity of the piers, as well as strengthened the whole range of the wall. Their towers strengthened the quoins of the walls, and besides admitted of staircases being formed within them to communicate with every story of the building, as also with the roof itself. The roof of King's College Chapel at Cambridge is justly esteemed the finest specimen of arching in existence, and exhibits at the same time an elaborate display of art and workmanship in every end of its departments. It consists of a series of arches, one passing through the whole building, and several others which find their centres in the several side buttresses; these are locked together in their intersections or apexes by a large key-stone shaped wedge-like, surrounded by additional keys cone-like, which altogether form a circular key at each intersection of the groin, with the square-shaped key-stone in its centre. These are placed in the centre of every compartment at equal distances along the central rib, which passes from East to West. A small rib intersects this, and crosses the roof almost in a horizontal line, and a much larger rib running parallel with it springs from the capitals of the clustered columns which run up between the windows, taking its spring directly against the buttress. Hence is supported this truly magical roof by a series of double arches, excentric to each buttress, with one main arch passing through the whole; yet all materially dependant on each other, and suspending that weight of stone which appears laid almost flat from side to side of the chapel. It is asserted by Malden, that the stones composing the groining are not more than three inches in thickness; they, however, vary, and are nearer to six inches. The keys are large and well fitted; besides they drop down as pendants, and are richly carved. There is a tradition which has been repeated by every writer who has written about this edifice, taken from Walpole's Anecdotes of the Arts, that Sir C. Wren became so much delighted with the style of this vaulting that he went once a year to survey it, and said, "that if any man would shew him where to place the first stone, he would engage to build such another." That the most accomplished architect of his time could commit himself by making so futile an observation is doubtful. It is nevertheless certain, that in this roof will be found successfully executed one of the most difficult tasks in architecture.

Masons employ certain technical phrases by which they designate every part of their work employed in building, some of which have been previously noticed; and in point of the value of each description of work, that is ascertained by a datum to be hence explained, and which has arisen from out of the experience attending on the general way adopted for the admeasuring of artificers' works. It does not appear to have been a very early practice among the surveyors and masons to separate all the distinct portions of labour which are employed about their hewn stone into the several different species, calculating the difficulty in each, and apportioning a value commensurate, which is now the common and universal practice. This manner of assessing the value of the labour and also of the materials, arose in its beginning from out of necessity, there having been found no other means of putting down the avarice and injustice of the master artificers. On its first introduction it met with very general opposition from all mechanics; but its rationality, together with its truth and accuracy soon gave it that ascendency over this selfishness which it was so well calculated to produce. Hence at this time every part of masonry as well as other artificers works are divided and again subdivided into all their several distinct parts, a value being assigned to each, which is found adequately to remunerate them for all their toil as well as the incidental expenses attending on the execution and erection of their several works.

In the admeasuring of mason's work the measurer is provided with two rods, commonly of five feet in length each, divided into five equal parts or feet, and each foot again subdivided into halves and quarter feet: sometimes the feet are also drawn in inches, but this latter method is by no means universal. When the stone to be measured approximates to fractions, the common rule is applied to ascertain them. All the stone is first measured, beginning at that which is fixed nearest to the top of the building, and then taking the labour to it; and every piece of stone which exceeds in its thickness two inches is valued by the cubic foot, and all other stones under that thickness are deemed to be slabs, and are

are valued at per foot superficial; these latter generally embrace the paving-stones of all descriptions, as well as chimney-pieces, copings, &c. There are also some portions of the labour as well as the stone which are valued by the foot measure running; of this class are the groovings in lusticated work, flutings in the shafts of columns] and pilasters, joints in gallery floors, called (joggled joints,) rebates in stairs, with the throatings to cills and copings, &c. &c. In the latter description may be included the various sorts of copings employed on the tops of walls and parapets, narrow slips to chimney-pieces, &c. &c. The dimensions are all accurately put down in a book, which for convenience is ruled into three divisions on its left-hand side, the middle division being about one-third of the width of those on its sides; this middle column is that in which the inches and parts are expressed, and in the left-hand column the feet, together with the number of times the dimension is to be repeated or added, and the last for placing the quantities when cubed and squared; for in taking the dimensions it often happens that there may be several pieces of stone of the same size, and this the measurer marks in his book, as well as at the same time writing down the nature of the stone, and also the species of labour about it. His dimension book stands thus:

3/6 : 0 3 : 0 : 9	3 : 4½	Portland Landing.
3/7 : 6 3 : 9	84 : 4	Plain Work Do.
3/7 : 6	22 : 6	Groove Do.

By thus arranging the dimension book, every particle of stone and labour on it is ascertained with the greatest accuracy and dispatch; they are all afterwards to be abstracted, which consists in ruling out a loose sheet of paper into as many columns or divisions as are required for all the several species of work which has been measured, and writing over the head of each of the columns the particular kind to be inserted in it; for instance, beginning with cube of Portland, all of it which has been measured is brought into the column under that head, plain-work under its head, also sunk-work, moulded work, and the several running measures all stand respectively; and when so separated, they are to be cast up at the bottom of each several column, where is to be seen the whole of the several quantities, after which they are made out into bills, beginning with the cubes first, then the superficies, and lastly the running measures. The works which are valued singly or by their number, are similarly classed and placed last of all at the bottom of the account. For thus measuring, cubing, and squaring the quantities, and valuing and finishing the account, surveyors' charge two and a half per cent on the gross amount.

The plain-work on stone consists merely in the cleaning up of its surface, and the rule for finding how much of it is to be measured, is by observing that the mason is entitled to all that is not covered, that is, to every part of it which may be seen. Sunk-work embraces that kind of labour to stone which requires the surface or any other portion of it to be sunk down by chiselling it away. The tops of all window-cills, for instance, are sunk for the purpose of more readily conveying away the water which falls on them. Moulded-work consists in forming on the edges of the stone certain forms, known in architecture as mouldings, that is, to make it more obvious. Cornices, architraves, and such parts of an edifice in which stone is employed are fashioned into a variety of curved or other forms. The dimensions of moulded work is ascertained by girting it with a string or piece of tape over to every one and into all its several parts, and then measuring the length of the string or tape so girted, which will be the width of the moulded-work, and the length of the cornice, &c. &c. will be its length, which when squared together will give the superficial quantity of moulded-work. Masons have also their circular-work; this kind of labour is admeasured in the same way as has been described for the moulded-work, viz. by girting it all round. There are distinct valuations for every one of these different species of labour. Nevertheless, it is not deemed here essential to recite them, as they vary as the price of the workmen's wages does, except in London where they are uniform, but in the country they are somewhat lower, the value of workmanship being less by reason of the men having much less wages.

Masonry en pise.

This is a species of building entitled to considerable attention, arising from out of its œconomy as well as its general utility. Every country abounds with the materials from which it may be formed, and in all nations it may be had recourse to for the building of useful as well as ornamental dwellings with fewer tools and with less of mechanism and machinery than is required for any kind of building now practised. In the year 1791, a work was published at Paris by M. Francois Cointereax, containing an account of a method of building strong and durable walls and houses with no other materials than earth, and which has been practised for ages in the province of Lyons, though little known to the rest of France or any other part of Europe. It appeared to be attended with so many advantages, that many gentlemen in this country who employ their leisure in the study of rural economy, were induced to make trial of its efficacy, and the event of their experiments has been of a nature to make them wish by all possible means to extend the knowledge and practice of so beneficial an art. With a view to promote this desirable end, the account contained in the following pages has been extracted from the French work, and it will be found to contain every necessary instruction required by those into whose hands the original work may not have fallen, or who being unacquainted with the language may have been prevented from consulting it. The appearance of those

those wretched hovels which are built with mud in some parts of England, will perhaps dispose many persons to doubt the strength and durability of houses which are composed of no other materials than earth. The French author says, " the possibility of raising the walls of houses two or even three stories high, with earth only, which will sustain floors loaded with the heaviest weights, and of building the largest manufactories in this manner may astonish every one who has not been an eye-witness of such things." But it is hoped that a description of the manner of building will sufficiently explain the reason of its superiority.

The word pisé, or en pisé, is a technical term made use of in the country where the work about to be described is in common practice, and it has been retained because it cannot be rendered by any adequate word in the English language. Pisé is a very simple manner of operation; it is merely by compressing earth in moulds or cases that we may arrive at building houses of any size and height. This art, though until very lately confined to the single province of the Lyonese in France was known and practised at a very early period of antiquity, as appears from a passage in Pliny's Natural History, lib. 34. c. 14, which is exactly a description of this manner of building. M. Goiffon, who published a treatise on Pisé in 1772, is of opinion that the art was practised by the Romans, and by them introduced into France; and the Abbé Rozier, in his Journal de Physique, says, " that he has discovered some traces of it in Catalonia," so that Spain, like France, has a single province in which this ancient manner of building has been preserved. The art, however, will deserve to be introduced into more general use. The cheapness of the materials which it requires, and the great saving of time and labour which it admits of, must recommend it in all places and on all occasions. But the French author says, " that it will be particularly useful in hilly countries, where carriage is difficult and sometimes impracticable; and for farm-buildings, which as they must be made of considerable extent, are usually very expensive without yielding any adequate return. All earths are fit for the purpose when they have not the lightness of poor lands nor the stiffness of clay; secondly, all earths fit for vegetation; thirdly, brick-earth; but these if they are used alone are apt to crack, owing to the quantity of moisture which they contain. This, however, does not hinder persons who understand the business from using them to a good effect. Fourthly, strong earths with a mixture of small gravel, which for that reason cannot serve for making either bricks, tiles, or pottery. These gravelly earths are very useful, the *best* pisé is made of them. These general principles may suffice without over-burdening the memory of the reader, and from the following remarks may be known what earths are fittest to be employed by themselves—when those have been described, it will remain to point out such as must be mixed with others, in order that they may acquire the necessary quality. The following appearances indicate that the earth in which they are found are fit for building; for instance, when a pick-axe, spade, or plough brings up large lumps of earth at a time; when arable land lies in clods or lumps: when field-mice have made themselves subterraneous passages in the earth, all these are favourable signs. When the roads of a village having been worn away by the water continually running over and through them are lower than the contiguous lands, and the sides of those roads support themselves almost upright, it is a sure mark that the pisé may be executed in that village. One may also discover the fitness of the soil by trying to break with one's fingers the little clods of earth in the roads and find a difficulty in so doing, or by observing the ruts of the road in which the cart-wheels make a sort of pisé by their pressure; whenever there are deep ruts in a road one may be sure of finding abundance of proper earth. Such earth is found at the bottom of slopes of low lands that are cultivated, because every year the rain brings down the fat or good earth. It is frequently found on the banks of rivers, but above all it is found at the foot of hills where vines are planted. In digging trenches and cellars for building, it generally happens that what comes out of them is fit for the purpose.

As it may sometimes happen that earth of a proper quality is not to be found on the spot where it is intended to build, it becomes of importance to attend to the method of mixing earths; for though the earth which is near at hand may not of itself be proper, it is very probable that it may be rendered so by the mixture of a small quantity of another earth fetched from a distance. The principle on which a mixture must be made is very simple; strong earths must be tempered with light; those in which clay predominates with others that are composed more of chalk and sand; and those of a rich glutinous substance, with others of a poor and barren nature. The degree in which these qualities of the earths prevail, must determine the proportions of the mixture, which it is impossible here to point out for every particular case but which may be learnt by a little practice. It would not be amiss to mix with the earth some small pebbles, gravel, rubbish of mortar, or in short any small mineral substance; but none of the animal or vegetable kind must be admitted. Such hard substances bind the earth firmly between them, and being pressed in all directions contribute very much to the solidity of the whole, so that well worked earth in which there is an admixture of gravel becomes so hard in about two years time, that a chisel must be applied to break it as though it were freestone.

First Experiment to ascertain the Qualities of Earth proper for making Pisé.—Take a wooden tub or pail without a bottom, dig a hole in the ground of a court or garden, and at the bottom of that hole fix a piece of stone flat and level, place your tub upon the stone, filling round it the earth that has been dug out to make the hole, and ram it well that the tub may be enclosed to prevent its bursting; then ram into the tub the earth you mean to try, putting in at each time about

the thickness of three or four fingers' breadth; when this is well rammed, add as much more and ram it in the same manner, and so for the third and fourth, &c., till the earth is raised above the brim. This superfluous earth must be scraped off extremely smooth, and rendered as even as the under part will be which lies on the stone. Loosen with a spade the earth round the tub, and you will then be able to take it out, and with it the compressed earth that it contains; then turn the tub upside down, and if it be wider at the top than at the bottom, as such vessels usually are, the pisé will easily come out; but if it should happen to stick let it dry in the air twenty-four hours, you will then find the earth is loose enough to fall out of itself. You must be careful to cover this lump of pisé with a little board, for though a shower of rain falling in an oblique direction will not injure it, yet it may be a little damaged if the rain fall perpendicular, and especially if it receive it so for any length of time. Leave the lump exposed to the air, only covered over with a board or flat stone; and if it continue without cracking or crumbling, and increases daily in density and compactness as its natural moisture decreases by evaporation, you may be sure that the earth is fit for building. But you must remember that it is necessary that the earth employed should be taken from a little below the surface of the ground, in order that it may be neither too dry nor too wet. It must be observed also, that if the earth is not well pressed around the outside of the tub before it is filled; though the hoops were of iron they would burst, so great is the pressure of the beaten earth against the mould, of whatever size it may be.

Second Experiment.—This trial may be made in the house: having brought from the field the earth you want to try, press it in a stone mortar with a pestle of wood, brass, or iron (the latter is best), or with a hammer; fill the mortar above its edge and then with a large knife or some other instrument take off the superabundant earth even with the brim; if you then find that the earth will not quit the mortar you must expose it to the sun or near a fire, and when it is sufficiently dry it may be taken out without difficulty by turning the mortar upside down on a flat stone or on the floor. It will have the shape of the mortar, and if exposed as above directed will shew the qualities of the earth.

In building en pisé and preparing the earth all the operations are very simple and easy; there is nothing to be done but to dig up the earth with a pick-axe, break the clods with a shovel so as to divide it well, and then lay it in a heap, which is very necessary; because as the labourers throw up that heap the lumps of earth and large stones will roll to the bottom, when another man may break them or draw them away with a rake. It must be observed, that there should be an interval of about an inch and a quarter between the teeth of the rake, so that the stones and pebbles of the size of a walnut or something more may escape, and that it may draw off only the largest. If the earth that has been dug has not the proper quality, which is seldom the case, and it be necessary to fetch some better from a distance, then the mixture must be made in this manner; one man must throw one shovel-ful of the best sort, while the others throw five or six of the inferior sort on the heap, and so more or less according to the proportion, which has been previously ascertained. No more earth should be prepared than the men can work in one day or a little more, that they may not be in want when about the building; but if rain be expected you must have at hand either planks, mats or old cloths to lay over the heap of earth, so that the rain may not wet it, and then as soon as the rain is over the men may resume their work, which without this precaution must be delayed; for it must be remembered that the earth cannot be used when it is either too dry or too wet, and therefore if the rain should wet it after it has been prepared, the men will be obliged to wait till it has recovered its proper consistency; a delay which would be equally disadvantageous to them and their employer. When the earth has been soaked by rain, instead of suffering compression it becomes mud in the moulds, and even though it be but a little too moist it cannot be worked; it swells under the blows of the rammer, and a stroke in one place makes it rise in another. When this is the case it is better to stop the work, for the men find so much difficulty that it is not worth while to proceed. But there is not the same necessity of discontinuing the work when the earth is too dry, for it is easy to give it the necessary degree of moisture in such a case; to do which it should be sprinkled with a watering-pot, and afterwards well mixed up together, it will then be fit for use. It has already been observed that no vegetable substance should be left in the earth, therefore in digging, as well as laying the earth in a heap, great care should be taken to pick out all sprigs and herbs, all bits of straw or hay, chips or shavings of wood, and in general every thing that can rot or suffer a change in the earth.

Implements used in Buildings of Pisé.—Besides the common tools, such as spades, trowels, baskets, watering-pots, &c., a hatchet will be required as well as a plumb, rule, hammer, and nails. The other machinery consists of a mould and a rammer, &c., of which it will be necessary to give a particular description accompanied by drawings.

Plate II. *Fig.* 1. is one side of the mould in which the earth is to be compressed, and seen on its outside.

Fig. 2, the other side seen within-side.

Fig. 3, the head of the mould seen without-side.

Fig. 4, the other face seen within-side.

Fig. 5, the wedges to secure the upright posts in the joists, *Fig.* 9 and 10.

Fig. 6, a round piece of wood called the wall-gauge.

Fig. 7, one of the upright posts seen on its flat side with its tenon to enter the mortise in the joists.

Fig.

Fig. 8, The same on its back also with its tenon.

Fig. 9, a joist in which the mortises are made to receive the tenon of the uprights and wedges seen flatways.

Fig. 10, the same with its side and bottom seen.

Fig. 11, the mould for the pisé wall put together, in which are seen all its several parts.

Fig. 12, the rammer (or *pisoir*) for ramming the earth in the mould.

For the construction of the mould take several planks each ten feet long, of some light wood, in order that the mould may be easy to handle: deal is the best, as being least liable to warp, to prevent which the board should be straight, sound, well seasoned, and with as few knots as possible; let them be ploughed and tongued together and planed on both sides. These planks so prepared should be fastened together by four good strong ledges, as seen *Fig.* 1. The mould must be two feet nine inches in height, and two handles composed of pieces of strong rope should be affixed to each of the sides (*see Figs.* 1 and 2.). The head of the mould, which serves to form the angle of the building must be made of two narrow pieces of wood ploughed, tongued, and ledged together; its breadth eighteen inches and height three feet, and planed on both of its sides (see *Figs.* 3 and 4), where it may be remarked that this part of the mould diminishes gradually to the top, in order that the wall may be made to diminish in the same degree; all the boards mentioned for making the case of the mould should be of whole or one inch and a quarter deal. The wedges, *Fig.* 5, must be at least an inch thick and from eight to twelve inches long: and as to the gauge, *Fig.* 6, it must be cut in its length equal to the thickness of the wall you mean to erect. The six or eight ledges that are necessary to secure the two large sides of the mould serve also to receive a corresponding number of upright posts, standing on a similar number of joists. The posts or uprights, *Figs.* 7 and 8, may be made of either wood sawed square, or of round wood of any kind: so that one may use indifferently the ends of rafters, joists, small trees or their branches. These posts are to exceed the height of the mould by eighteen inches, they must therefore be about five feet high, including the tenons (which should be six inches long), and in their scantling about three inches by four inches. That part which is to bear against the ledges of the mould must be flat and strait, the other sides need not be worked with so much truth. The joists, *Fig.* 9, also may be made of the same sort of stuff, and should be three feet six inches long and in scantling three inches and a half by three inches; on the broad part of which must be made the two mortises (as marked *Fig.* 9 and 10), each ten inches and a half long and about one and half inch wide, and at each end three and a half inches must be left projecting beyond the mortises, so that the interval between for the mould will remain fourteen inches. These dimensions must be observed in order that the two sides of the mould may incline towards each other, and the thickness of the wall be gradually diminished till it be reduced to fourteen inches at the roof. The dimensions of the joists then are as follows, viz.

The two ends remaining beyond the mortises three and a half inches each	—: 7
The two mortises ten and a half inches each	1 : 9
The interval between the mortises	1 : 2
Total length of the joists, *Fig.* 9 and 10	3 : 6

The most simple things are sometimes difficult to be understood without being seen, an elevation of the section therefore of the whole machine has been annexed (see *Fig.* 11). The following is a list of its several parts enumerated in the same order, and which the workmen must be careful to observe when they are about to erect the mould.

Section of the Mould on the Wall.

A, a stone or brick foundation, one foot six inches thick, on which a wall of earth is to be raised.

B B, the joists placed across the foundation wall.

C C, the two sides of the mould, including between them three inches of the foundation wall.

D D, the upright posts, the tenons of which fit into the mortises of the joists.

E, the wall gauge, which affixes the width of the mould at top, and which is shorter than the thickness of the wall at bottom for the purpose of regulating the dimension of the wall to be erected.

F, a cord about half an inch in diameter, making several turns round the tops of the posts to secure the frame at top.

G, a round stick, which by being wound round fastens the cord and holds the posts tight together.

H H, the wedges which enter into the mortises in the joists, and keep the posts and moulds firmly fixed against the wall.

Such is the process employed in erecting the mould, a contrary order must be observed in taking it to pieces. To do which, the rope must be unloosened, the wedges taken out, and the posts, the mould, and the joists removed, in order to fix up the whole again.

The instrument with which the earth is rammed into the mould is a tool of the greatest consequence, and on which the firmness and durability of the pisé will much depend; in short, the perfection of the work will be in proportion to its goodness. It is called a *pisoir*, or rammer, and though it may appear very easy to make, yet more difficulty will be found in the execution than is at first apprehended; a better idea of its construction may be formed by examining *Plate* II, *Fig.* 12, in which it is delineated, than any words can convey. It should be made of some kind of hard wood, either oak, ash, beech, &c., or, which is preferable, the roots of either of these.

Method of working Pisé.—Let us not confound pisé with that miserable way of building with clay, or mud more properly, mixed with hay or straw, which is often seen in country villages. Though some have been unable

able or unwilling to distinguish between them, nothing in reality can be more different. Those wretched huts are built in the very worst manner that could be imagined, whereas pisé contains all the best principles of masonry, together with some rules peculiar to itself. *Plate* II. *Fig.* 13, represents the plan of a cottage arranged for two rooms; A A, the windows; B B, the fire-places; C, the cross or partition-wall; D D, the door-ways, the building of which will be described according to the method of Pisé.——To begin with the foundation, as seen *Fig.* 11, A: this may be made of any kind of masonry or brick-work that is durable, and must be raised to the height of two feet above the ground, which is necessary to secure the walls from the moisture of the earth, and the splashing of the rain which will drop from the eaves of the roof. When the foundation-walls are built up level all round the cottage, and eighteen inches thick, mark upon them the distances at which the joists are to be set for receiving the moulds, those distances should be three feet each from centre to centre of the joists (see B B, *Fig.* 11); each side of the mould being ten feet long, will divide itself into three lengths of three feet each and leave six inches at each end, which serves to lengthen the mould at the angles of the house, and are useful for many other purposes. After having set all the joists of the mould in their places, the masonry of the foundation must be raised up six inches, that is, till it be level with the upper face of the mould-joists; there will therefore be upon the whole a base of two and a half feet, which in most cases will be found more than sufficient to hinder the rain, frost, snow, or damps from injuring the walls. Raise the mould immediately on this new masonry, placing it immediately over one of the angles of the wall. The method of raising the mould has already been described. The head of it (See *Plate* II, *Fig.* 3 and 4) is to be placed against the angle, and should have eighteen inches in breadth at the bottom, and seventeen and a half inches only at the top; thus the sides of the mould will incline upwards, and produce that diminution in the thickness of the wall which is usual in buildings of this nature. The wedges (*Fig.* 5) must then be driven in, and the upright posts (D D, *Fig.* 11) well secured by cords, and the head of the mould fixed by iron pins or with screws and nuts; after which the preparation of setting the mould is complete, and the workmen may begin the filling up of the pisé wall. A workman should be placed in each of the three divisions of the mould, taking care to put the best at the angle, as it will be his business to direct the work of the other two, and to occasionally apply a plumb rule to the wall and mould, to prevent the mould from swerving from its upright position. The labourers who dig and prepare the earth, must give it in small quantities to the workmen in the mould, who after having spread it with their feet, begin to press it with the rammer. They must only receive so much at a time as will cover the bottom of the mould to the thickness of three or four inches; the strokes of the rammer should be given close to the sides of the mould, and afterwards applied to every other part of the surface; the men should cross their strokes so that the earth may be pressed in every direction. Those who stand next to one another in the mould should so regulate their strokes as to be at the same time under the coro, because that part cannot be got at without difficulty and must be struck obliquely; with this precaution the whole will be equally compressed. The man who is stationed at the angle of the wall, should beat carefully against the head of the mould, and for the sake of the appearance, or perhaps to increase the strength of the building, it is usual to spread at every six inches a layer of mortar near the head, in imitation of the joints in stone-work. Care must be taken that no fresh earth is received into the mould till the first layer is properly beaten, which may be ascertained by striking it with the rammer, the strokes of which should leave hardly any impression on the face. They must proceed in this manner, putting into the mould layer after layer till it is filled up completely; when this is done the machine may be taken to pieces, and the earth which it contained will remain firm and upright, of about nine feet in length and about two feet and a half in height. The mould may be then replaced for another length, including one inch of that which has first been completed, and that no joints may appear in the work, the different lengths are united and made to press one on another. In the second lengths and most of the following, the head of the mould is useless, as it is only made use of at the quoins or angles. When the workmen have gone round the whole building, taking the mould to pieces and putting it together again successively, they must begin upon the partition-wall: in it the head of the mould must be used, as the jaumbs to the doors are to be squared like the angles of the house. When the jaumb next to a cross-wall is very narrow it must be made of other materials such as brickwork, &c. The first course being thus completed we proceed to the second; and here it must be observed that, if in laying the first course we begin with an angle, we must proceed with the second in a contrary direction. It may be easily conceived that with this precaution the joints (see *Fig.* 14) of the several lengths will be inclined in opposite directions, which will contribute very much to the firmness of the work. There is no reason to fear overcharging the first course with the second, though but just laid, for *three* courses may be laid without danger in *one* day. The grooves for receiving the joists should be marked out at the distance of three feet from one another, as before described, but not immediately over the former grooves (see *Fig.* 14, A), but over the middle points between them; these grooves must be chased or cut out of the pisé with a pickaxe, and the second course completed in the same manner as the first, except that it must be proceeded in, in a contrary manner, as before observed, and that the head of the mould and also the wall-gauge must be diminished, in order that the same inclination of the sides to one another which was given in the first course may be persevered

severed in for the second, &c. It must, however, be remarked, that this second course is not exactly to be continued like the first, as it is necessary that the partition-wall should join or bind (see *Fig.* 14, B B) into the external wall, or rather that all the walls of the building, whether outside or partition-walls, which meet at an angle or otherwise, should cross each other at every corner; in pursuance, therefore, of this rule, when the work has been advanced from E to F (see plan *Fig.* 13) or perhaps not quite so far as F, leave the exterior end walls and turn the mould to the partition c, applying the base of it to F, and when the work has been carried along the partition wall as far as the doorway D, bring back the mould to the part which remained unfinished in the exterior wall, and after having filled up the space, carry the mould on, beyond the partition wall, and complete the course. The reason why the partition wall in the side opposite (or where the small jaumb of the door is) is not to be connected in the same manner with this interior wall, has already been given; viz. that it ought to be made of wood or brickwork and not of pisé; but the third course must be carried over the head of the doorway, and join into the wall as directed for the other side. This description of the two first courses is equally applicable to all the others, and will enable any person to build a house with no other materials than earth, of whatever height and extent he pleases. With respect to gables (if any are designed to be made) they cannot be crossed in their courses as they are detached from one another, but as their height is inconsiderable, and as they are besides connected together by the roof, that part of the work will not be of any material consequence for them. They may be made without any difficulty by merely marking their inclination in the mould and filling in and working up the earth accordingly. It has been observed that each course will be two and a half feet high if the mould is two feet nine inches, for the mould must invariably include three inches of the course beneath, for this reason the grooves are made six inches deep, though the joists are only three inches in thickness. If the directions which have been given for diminishing the thickness of the walls are observed, that thickness will be reduced to fifteen inches at the roof in a house consisting of six courses of pisé in height, for in each course there will be an inclination of half an inch. The gables might be reduced to fourteen inches only in thickness, as an interval of fourteen inches only was left between the mortises of the joists, and by increasing or diminishing that interval the thickness of the walls may be regulated at pleasure. Such is the method of building which has been practised by the Lyonnese for many centuries. Houses so built, are strong, healthy, and very cheap, they will last a great length of time, for the French author says, "he had pulled down some of them which from the title deeds in the possession of the proprietors, appeared to have been erected 165 years, though they had been but ill kept in repair. The rich traders of Lyons have no other way of building their country houses. An outside covering of painting in fresco, which is attended with very little expense, conceals from the eye of the spectator the nature of the building, and is a handsome ornament to the house. That kind of painting has more freshness and brilliancy than any other, because water does not impair the colours. No size, oil, or any thing expensive is required for it, manual labour is almost all that is wanted either by the rich or the poor. Any person may make his house look as splendid as he pleases for a few pence laid out in red or yellow ochre, or in other mineral colours. Strangers who have sailed upon the Rhone probably never suspected that those beautiful houses which they saw rising on the hills around them, were built of nothing but earth, nay, many persons have dwelt for a considerable time in such houses without ever being aware of their singular construction. Farmers in that country generally have them simply white-washed; but others who have a greater taste for ornamenting, add pilasters, window-cases, pannels and decorations of various kinds. There is every reason for introducing this method of building into all parts of the kingdom, whether we consider the honour of the nation as concerned in the neatness of its villages, the great saving of wood it will occasion and the consequent security from fire, or the health of the inhabitants, to which it will greatly contribute, as such houses are never liable to the extremes of heat and cold. It is attended with many circumstances that are advantageous to the state as well as to individuals. It saves both time and labour in building, and the houses may be inhabited almost immediately after they are finished, for which latter purpose the holes made for the joists of the mould should not be closed up directly, for the air, if suffered to circulate through them, will dry the walls more speedily.

The Method of forming the Apertures in Pisé Buildings.—The openings for the doors and windows must be left at the time of building the walls. This may be done by placing within the mould one or two of the heads of the mould as may be found necessary, wherever the wall is to terminate and the opening to commence. They should be made sloping a little in order to leave room for the frames and sashes. The exterior decorations of the windows and doors are usually made by the rich of stone or bricks, and by the poor of wood, which latter have a bad effect on the appearance of the house, as wood will never unite well with pisé-work; and, notwithstanding the greatest precautions, the exterior covering will break and fall off the wood, whereas stone or brick-work unite perfectly with the pisé, and retain their plaster, and, of course, their paint, of which it forms the ground. The chimney-pieces (BB, *Fig.* 13) are laid and united with the walls in the same manner as in a common building, and the flues are also very firmly connected with them, being made of brick-work. But a very particular advantage is that the apartments may be very handsomely finished without making any jaumbs to the inside doors, either

either of stone or wood. The facings of wood to the earthen wall will render jaumbs unnecessary, and why should the expense of any other finishing be incurred, when the doors may be hung on the grounds or wainscot of the apartments?

Beating or compressing earth is used in many different sorts of work. The ancients employed it in making their rough walls; the Spaniards, the French, and others, for some of the floors of their apartments. The intent of the ancient architects, when they recommended the beating of cement and other compositions used in buildings, was to prevent them from shrinking or cracking, and it is employed for the same purpose in buildings which are made of earth. The beating, by repeated strokes, forces out from the earth the superfluous water which it contained, and closely unites all the particles together, by which means the natural attraction of the particles is made to operate, as it is by other causes in the fermentation of stones. Hence arises the increasing of strength and the astonishing durability which houses of this kind are found to possess.

On the Height of Pisé Wall which may be raised in a Day.—In one single day three courses, of about three feet in height each, may be raised one over another, so that a wall of earth of about eight or nine feet, or one story high, may be raised in one day. Experience has proved, that as soon as the builders have raised their walls to a proper height for the flooring, the heaviest beams and rafters may without danger be placed on the walls thus newly made, and that the thickest timber of a roof may be placed on the gables of pisé the very instant they are completed.

To make good walls of pisé it is not sufficient that the earth be well beaten, we must also learn to unite them well together. In houses of brick or stone, to consolidate their parts they make use of angles and binders of free-stone, and of iron-braces and cramp-irons, which are very expensive; but here the binders cost very little, consisting only of thin pieces of wood, a few cramps and nails, and these are found sufficient to give the greatest solidity to buildings of pisé. The first course H, *Fig.* 13, being laid on the front and inner walls of a house, we begin with the second, and if for the inferior course has been directed from G to E, *Fig.* 13, it must for this second be directed from G to H; but before this second course is began, lay at the bottom of the mould a board about five or six feet long, resting on the angle G, and extending lengthwise towards H; this board must be rough as the sawyers have left it, and about an inch thick, and in breadth about eight, nine, or ten inches, so that there may remain on each side four or five inches of the earth of the wall, which is eighteen inches in thickness; by this means the board will be entirely concealed in the body of the pisé, and when there placed, neither the air nor damp can reach it, and, of course, there is no danger of its rotting. This has been often proved by experience, as in taking down old houses of pisé such boards have always been found perfectly sound, and many that have not lost the colour of new wood. It is easy to conceive how much this board will equalize the pressure of the work raised above it, and will also contribute to bind together the two lengths G E, and to strengthen the angle G; but this is not all, it is useful (particularly when the earth is not of a very good quality) to put ends of planks into the pisé after it has been rammed to about half the height of the mould. These ends of planks should be only ten or eleven inches long, to leave, as before, a few inches of earth on each side of the wall; if it is eighteen inches thick, they should be laid crosswise (as the plank before-mentioned is laid lengthwise) over the whole course, at the distance of about two feet from one another, and will serve to equalize the pressure of the upper parts of the work on the lower course of the pisé. The boards mentioned need only be placed at the angles of exterior walls, and in those parts where the partition-wall joins to those of the exterior wall. The same directions that have been here given for the second course must be observed at each succeeding course up to the roof. By these means the reader will perceive that an innumerable quantity of holders or binders will be formed which sometimes draw to the right, sometimes to the left, of the angles, and which powerfully unite the front walls with those of the partitions, the several parts deriving mutual support from one another, and the whole being rendered compact and solid. Hence these houses, made of earth alone, are able to resist the violence of the highest winds, storms, and tempests. The height of each story being known, boards of three or four feet in length should be placed before-hand in the pisé, in those places where the beams are to be fixed; and as soon as the mould no longer occupies that place the beams may be laid on for each story, and the pisé may be continued as high as the place on which you intend to erect the roof.

On building Park or Garden Walls en Pisé.—With respect to walls for enclosures of parks, gardens, yards, &c., the mould must be fixed in an angle, or against a building, if the wall is to reach so far, and the workmen must proceed from thence to the other extremity of the wall, and when they have fixed the first course they must raise the mould to make the second, returning to the place where they began the first. But when a very great enclosure is to be made, as, for instance, a park-wall, then, for the sake of speed, it is necessary to set several moulds and men to work. In such a case, a mould should be placed at each end, and the number of men be double; they will work at the same time, and meet in the middle of the wall, where they will close the first course, after which each set of men raise their mould to make their second course, and both setting out again for the middle, continue working in opposite directions towards the ends where they first began. Besides the advantages of strength and cheapness this method of building possesses that of speed in the execution. That the reader may know the time that is required

required for building a house or an enclosure, he need only be told that a mason used to the work can, with the help of his labourer, when the earth lies near him, build in one day six feet square of the pisé. If two men can build in one day six feet square, it is evident that six men, which is the necessary number to work the mould (viz. three in the mould and three to dig and prepare the earth), will build, in the course of sixteen days, or three weeks at most, a house similar to plan delineated *Plate* II, *Fig.* 13, and such a house is estimated to contain two hundred and eighty-eight feet square of wall. A very short space of time therefore is sufficient for a man to build himself a solid and lasting habitation. These facts, which have been proved by numberless instances, afford a proposition by which every one may determine the time that his house or wall will take in building, having first ascertained the number of feet it will contain.—Thus, if he wishes to have a wall five hundred and forty feet long, and six feet high, it will be finished in one month with one single mould and six men, and if he doubles both moulds and men it will be done in fifteen days. These are simple but necessary instructions, for they will prevent the inconvenience to which many are exposed from having the completion of their building protracted beyond the time that they originally expected. All persons who wish to build may hence contract with a builder that the work shall be finished on such a day, or that he shall indemnify them for all the losses which they may incur from his failure in the making good of his engagement.

On the Plastering necessary to Pisé Buildings.—The outside covering of plaster which is proper for pisé-walls is quite different from that which is made use of on any other walls; it is necessary too, to take the proportion for laying it on. If a house of pisé has been began in February, and completed in April, the covering may be laid on in the autumn, or, that is to say, five or six months after it is finished, or if it is finished in the beginning of November (at which time the masons generally give over working pisé) it may be laid on in the spring. In this interval the walls will be sufficiently dried; but it must not be imagined that it is drought or cold that extracts the moisture from the earthen wall; it is only the air, and particularly the north air, which is of itself sufficient either in summer or winter to dry a pisé wall thoroughly. If you happen to lay your plaster over them before the dampness is entirely gone off, you must expect that the sweat of the wall will cast off the plaster. To prepare a wall for plastering, indent them with the point of a hammer or hatchet without being afraid of spoiling the surface left by the mould; all those little dents must be made as close together as possible, and cut in from the top to the bottom, so that every hole may have a little rest in the inferior part, which will serve to retain and support the plaster. To do this the masons must make a small scaffold in the holes which the joists of the mould have left. This scaffold may be made in a few minutes, and when with the assistance of it they have indented the upper parts of the house, they must run a stiff brush over the indented surface to remove all dust or loose earth. The walls thus prepared, they may lay on the plastering, but before the manner of doing this is described it should be observed that there are two kinds of plaster that may be used in the pisé, viz. rough-cast and stuccoing. Rough-cast consists of a small quantity of mortar, diluted with water in a tub, to which a trowel of pure lime is added, so as to make it about the thickness of cream; stucco is nothing more than poor mortar, which the labourers make up in a clean place near the lime-pit, and carry to the masons on the scaffold. Such is the manner of preparing the coverings, let us now see the manner of employing them. For rough casting, one workman and his labourer are sufficient; the workman on the scaffold sprinkling with a brush the wall he has indented, swept and prepared, after which he dips another brush made of bits of reed, box, &c. into the tub which contains the rough-cast, and throws it with the brush against the wall; when he has covered with as much equality as possible so much of the wall as is within his reach, he lowers his scaffold, and stops up the holes of the joists with stones or old plaster, &c., does as before, and continues lowering his scaffold in the same manner till he comes to the bottom of the house. This rough-cast, which is attended with so little expense or trouble, is, notwithstanding, the best covering that can be made for pisé-walls, and for all other like constructions; it contributes to preserve the building, and though not beautiful, has the recommendation of being attainable by people in moderate circumstances. It is the peculiar advantage of these buildings that all the materials they require are cheap, and the workmanship simple and easy.

The process of stuccoing is very different. Two workmen and two labourers are requisite; the two workmen being on the scaffold, and one of the labourers making up the mortar, while the other carries it, with water, and serves the workmen. One of the workmen holds in his right hand a trowel, and, in the other, a brush with which he sprinkles the wall, having before well indented and swept it; after which he lays on a few trowels full of stucco, which he spreads as much as possible with the same trowel, and then he lays it on more, and thus continues his work. The second workman has also in his left hand a brush, and in his right a small wooden-float; he sprinkles water over the mortar his partner has spread, and rubs over the part he has wetted with this wooden-float. The reader easily perceives the progress of this work. The first workman lays on the plaster and advances gradually, the second follows and polishes; one labourer makes up the stucco, the other carries it and serves the workmen. By this progress the smoothest finish and cheapest plastering is made. At the same time that the plaster is laid on, it may also be whitened by the use of lime alone, which is

is also an object of economy, since it saves white-lead, &c. For this purpose, dilute lime in a tub of very clear water, and let a labourer take some of it in a pot and carry it to the workmen, who must lay it on with a brush; this, as well as all other colours, adheres to the plaster and never falls off, although it is used with water only, without either size or oil. This is to be attributed to the precaution of laying on the colour whilst the plaster is still wet, as it grows dry it incorporates mineral colours with its own substance, and makes them last as long as itself.

Lime is of very general utility, it is used in building, in plastering, and in white-washing; and it will appear from the chapter about to be added on Painting, that, for that purpose also, it may be employed with advantage. Those who intend to build therefore ought always to have a store of lime by them, and it should be slaked a long time before it is used to prevent crevices and blisters, which, without this precaution, will arise in the plaster, and give it so disagreeable an appearance that it will be necessary to do the work over again. The reason of it is this, there will always remain in the lime some particles that have not been slaked in the pit, as all the stones are not reduced to lime in the kiln, and those stones will resist the action of the water for a time and will burst from the plaster after it has been laid, leaving the crevices above-mentioned. This circumstance will not happen if the lime, after being slaked, is left to stand some time before it is used; indeed it would not be amiss to let it lie by a whole year.

With regard to the expense of walls of pisé, of which labour constitutes the principal, and as labour is dearer in some places than in others, the best mode of estimating it will be from the quantity of such work that a man can perform in one day. Mr. Salmon, of Woburn, has found, by employing a man in such work, that he will perform easily, in a day of ten hours, $1\frac{1}{4}$ square yards superficial, from which he has estimated the expense as follows:—

	s.	*d.*
Labour in making facing-composition, filling-in, and ramming, to a sixteen-inch wall, when the earth is at hand (labourers' wages being at Woburn 1*s.* 10*d.* per day), per yard superficial	2	2
Value of lime used in the composition rammed into the face of a yard superficial (lime being 8*d.* per bushel)	0	3
Lime and labour for rubbing-up and finishing the outside face of the wall	0	3
Total for finishing and facing on one side	2	8
If a garden wall, or otherwise, which will require facing and finishing on both sides . . .	0	8
Total for walls finished on both sides	3	4

On the Painting in Fresco to Pisé Buildings, &c.—That kind of painting, which is known by name of fresco, is the most beautiful and the cheapest of any, and it is that which the French author recommends for the decoration of pisé buildings. The most celebrated painters were very partial to it, and Rome has furnished many excellent models in its higher departments, which should engage us to restore it from that neglect and disuse into which it has without reason been suffered to fall. Whoever wishes to have his house painted in fresco, must have a painter ready, and place him on the scaffold with the workmen. The latter lay on the mortar as before directed, and are attentive to spread it very even to receive the paint. When they have finished one part they suspend their work to give the painter time to do his; for if they continued working on, the painter, who cannot go on so fast as they do, would find the mortar too dry, and the colours would not incorporate with it. It is absolutely necessary that the plasterer's work should be subordinate to that of the painter, for which reason it is sometimes so arranged, that the latter works, while the former are gone to their meals; and when, in his turn, he retires from work, he traces out the part that the plasterers are to cover during his absence, foreseeing how much he shall be able to paint in the course of the day. All these precautions are taken to prevent the too speedy drying of the mortar, and to save the proper time to lay on the colours whilst it is fresh.

Although this work does not profess to teach the art of painting in fresco, it may perhaps be found to contain directions sufficient for the execution of it in an ordinary manner. To make the colour you mean to give a country-house, dilute in a large tub a sufficient quantity of lime which has been slaked a long time: you must dilute, in another tub or pot, some ochre, either yellow or red, or any other mineral colour you please, but always in very clean water; after which, pour a little of the colour into the large tub, and stir it about with a stick or spatula, so as to mix it well with the lime. Take some of the colour on a brush and try it on a board or wall, and if it be too deep or too light add fresh lime or colour from the tub; and, by repeated trials, you will bring it to the tint you wish to give the house. The colour being made for the body of the house, the frames for the doors and windows are next to be considered, and a new colour chosen to distinguish them from the rest of the front. If the body of the house be painted yellow, or a pale red, the angles and frames may be white or blue; if it be grey, they may be yellow or deep red; and in all cases it will be a very easy matter to put the most suitable colours. The plasterers are equal to painting the fronts of houses in a common way; but when builders or proprietors wish to have them decorated in a superior way they must call in a painter, whose business it is to do it.

These paintings in fresco are more lively and more brilliant than any other, because the colours are not deadened by size and oil, which do not enter into their composition; their effect is surprising, and that pleasure may be had at a little expense.

Note.

Note.—The plaster proper to serve as a ground for fresco painting or colouring, is made of one part lime, and three parts clean, sharp, washed sand. This part of painting has been executed with great success at Woburn Abbey, and other places. It is not very usual to slake the lime in England so long before it is wanted, but it is an excellent practice, especially if it be wood-burnt.

In addition to the elaborate French-work on Pisé, there has now been published in the twenty-seventh volume of the Transactions of the Society of Arts, some very useful experiments made in it by Mr. Salmon, which may be found of great utility to such as propose making any buildings after the pisé manner.

MINING.

Mining is the art of digging into and penetrating the earth beneath its surface, either for the purpose of discovering and working veins of metallic ores and other valuable substances, or for forming subterranean passages for military operations.

To carry on all the processes of mining requires the combination of very considerable skill in several difficult branches of engineering. Most countries in which metallic veins are found, have the strata under the upper *soil*, consisting of rock of various degrees of hardness, it is therefore an essential part of the miner's art, and what indeed particularly distinguishes him from a common labourer, to be able to break ground of this sort under all the disadvantages of being cramped for room, exposed to constant streams of water, and not unfrequently to unwholesome air.

In Cornwall the workmen generally divide the ground, or rock, into two general classes, one of which they call *working-ground*, and the other is distinguished by the name of *shooting-ground*.

The first class includes all such kinds of rock as may be separated or broken by the use only of the *pick* and wedge, which latter is technically called a *gad*.

The latter denomination is applied to all rock that is so hard as to require the use of gunpowder, which is bored by tools of steel, and loosened and detached by the explosion of the charges rammed into the holes.

The tools used by the miners of Cornwall and Devon are simple, and in their hands very effective; the form of the principal ones is delineated in the annexed engraving (Mining, *Plate* I.)

The pick (*Fig.* 2) is usually of the shape shewn in the drawing, but it is varied a little for some purposes, or for different kinds of rock; the one side is used as a hammer, and is called the *poll*, it serves to drive the *gads*, or to detach and loosen projecting parts; the *point* is steel, carefully tempered, and drawn under the hammer to its proper form, in which considerable nicety is required, as one kind of point will not do for all kinds of ground. The weights of picks are likewise various according to the situation and circumstances in which they are to be used, but are never very heavy, as experience has fully shewn that a rapid succession of smart blows which may be given by a light tool produces more effect than a lesser number from a weighty instrument, which soon tires the workman.

The *gads* (*Fig.* 3) are wedges of steel, which are driven into crevices of the rock, or into small openings made with the point of the pick, and, in skilful hands, they serve to loosen ground of very dense texture.

The *miners' shovel* (*Fig.* 4) has a pointed form, which is necessary to make it possible to force it into or under the coarse and hard fragments of which the waste from a mine principally consists. It is furnished with a long handle somewhat bent, by which a man's power is applied in the most convenient form without stooping the body.

The tools for blasting, or, as it is technically called, *shooting*, consist of the

	Fig.
Sledge, or mallet, ...	7
Borer, ...	8
Claying bar, ...	9
Needle, or nail, ...	10
Scraper, ...	11
Tamping-bar, ...	12

Besides these tools there are required a powder-horn, rushes to be filled with powder, occasionally tin cartridges for very wet ground, and paper rubbed with gunpowder, or sometimes grease, for the *snufts* or fuses.

The borer (*Fig.* 8) is a bar of iron, with a steel end, formed like a thick chisel, and is used by one man holding it in the hole and constantly turning it round, while his comrade strikes the upper end with the iron sledge or mallet (*Fig.* 7). The hole is occasionally cleaned out by the scraper (*Fig.* 11), which is an iron rod turned up at one end; or, if the ground is very wet, and the hole fills with mud, a stick beat at the extremity till it forms a kind of brush is used, and is called a *swab-stick*.

Holes for blasting are generally about one inch and a quarter in the bore, and of various depths from ten or twelve inches to three feet, but these, as well as the position and direction in which they are bored, and the charge of powder employed, are subject to the skill and discretion of the miner. The rules by which he is guided are to direct the effort of the explosion to a part of the rock which is most easily displaced, and to proportion the charge to the effect required, so as to shake and loosen a larger portion rather than to blow out a lesser quantity.

Fig. 6 serves to explain the process of blasting, and represents a section of a hole ready for firing. When the hole is bored it must be made as dry as possible; to do which it is partly filled with good tenacious clay and a round iron bar, nearly fitting the bore of the hole, but somewhat tapering, and called the claying-bar; this is driven in with great violence, which so forces the clay into all the crevices of the rock, that when the bar is withdrawn, the hole usually remains dry. Where this plan fails from the great flow of water all round, it becomes necessary to use tin cartridges furnished with a stem or tube through which the powder may be inflamed. A section of one of these cartridges is shown in the *Plate*, *Fig.* 13.

When the hole is dry, either by clay, or otherwise, the proper charge of gunpowder is introduced, and the nail, a small taper rod which ought to be made of copper, is inserted, and reaches to the bottom of the hole; the hole is then ready to receive the *tamping*, which is the most difficult and dangerous part of the process. It is by this that the gunpowder is confined, and the effect produced; different substances are in use for ramming into the hole for this purpose; that most usually employed is any soft kind of rock, which is free from quartz or flinty matter. Small quantities at a time are introduced into the hole, and rammed very hard by the *tamping-bar*, which is held by one man, and struck with a sledge by another; this is continued until the hole is filled up, and the nail being then drawn out by putting a bar through the eye, and striking it upward, leaves a small perforation or vent for the rush which conveys the fire.

The danger of beating the tamping with iron tools in hard rock, and the many dreadful accidents that frequently happen in this operation, have led to the introduction of contrivances to diminish the risk; but though some of these have been well adapted for the purpose, yet, as they occasion a little more trouble, they have not been generally adopted by the miner. The simplest and best precaution against danger is to have the nail of copper instead of iron, but as the former is not so easily made or repaired by the smiths on a mine as the latter, they are not so well liked by the workmen.

The other modes of preventing danger in tamping is by employing substances to confine the gunpowder which require little or no force in beating them into the hole, and as dry sand will often serve the purpose if the rock is not very hard it may be sometimes used; but there are many cases in mines where it will not succeed, and therefore it is seldom attempted. A better substance to confine gunpowder in holes is good tough clay, and this will answer in many cases where sand will fail particularly in wet ground, or in holes that are inclined upwards, it will produce the proper effect in all but very hard rocks, and if the men could be induced to use it would undoubtedly tend to the saving many lives.

When the tamping is completely rammed in, and the nail drawn out, a small *vent* or *touch-hole* remains, which is to receive the *rush* to communicate the fire. Any small tube filled with gunpowder will answer for this purpose, but nothing is better or more easily prepared than those in common use. For this purpose, the green rushes which grow in wet marsh lands are chosen, and are selected as long and large as can be had. By making a slit in one side and drawing along in it the sharp end of a piece of stick, the pith may be taken out very completely, and from the elasticity of the skin of the rush the slit closes again. To fill this tube with gunpowder, the rush is held in one hand so as to pass through a small quantity of powder retained in the palm of the hand, and by opening the slit with a small wedge and pushing the rush along through the powder at the same time, it is made to embrace a quantity sufficient to communicate inflammation.

To fire the hole, one of these charged rushes is dropped through the vent, and is made steady by a piece of clay; a paper *snuft* is then fixed to the top, which is so adjusted as to burn a sufficient time to permit the man who fires it to retreat to a proper distance.

Fig. 6 represents a section of a charged hole in a rock. The portion which would be dislodged by the explosion is that part included between A and B. The charge of powder is shewn by the white part, which reaches as high in the hole as C: from that point to the surface of the rock the hole is filled with tamping, excepting the small orifice which contains the rush, and which has the snuff affixed at D.

Fig. 14 is a drawing of a wheelbarrow, such as is used under-ground for conveying ore and waste to the shafts: these barrows are very simple in their construction, and adapted to the narrow and low levels through which they have to pass. They are usually made all of deal, this timber being lightest and most fitted to the purpose. The wheel has a narrow band of iron round it.

Fig. 5 is an iron bucket, or, as it is called in Cornwall, a kibble, and is used for holding the ore and waste while it is drawn up the shafts by machines, worked by horses, called whims. Kibbles are generally made of wood, having very stout staves, very strongly bound with heavy iron binds or hoops, but as those made with iron plates are to be preferred, and need not much exceed the others in weight, we are glad to be able to exhibit a drawing of one of the latter of an approved form and construction.

A kibble, such as is used with horse-whims, holds about three hundred weight of ore, and one hundred and

and twenty kibbles will just clear a cubic fathom of rock.

Miners' work under-ground is chiefly divided into sinking, driving, and stoaping.

Sinking is applied to shafts, and to other smaller perpendicular openings from one level to another, usually called winzes.

Shafts are of different dimensions according to the purposes they are designed for; the largest kind is the engine-shaft, in which are generally placed the pumps for draining the mine of water, the ladders for the men, and a part divided off and called the whim-shaft, for the kibbles to pass up and down. *Plate* II (MINING) will be found to represent a perspective view of a part of the interior of one of these shafts.

A good engine-shaft measures about eight feet by twelve, though some are sunk of larger dimensions. Shafts intended only for hauling ores through, and those for air and foot-ways, may be about six feet by four.

In large shafts, a set of twelve men are usually employed; in smaller ones, eight, or even six, are a sufficient complement to keep the work going. They work two or three at a time, and relieve each other every six or eight hours, keeping good the whole twenty-four without intermission. The miners are attended by labourers, or winze-men, who haul up the stuff out of heir way as it is broken.

Sinking is contracted for by the fathom in depth, and the price therefore varies according to the dimensions of the shaft as well as according to the hardness of the ground, and the circumstances relating to water, air, &c. A medium price is about £20 a fathom for shafts at some depth from the surface, but some have cost £80, and others are executed as low as £5.

Driving is the term applied to the execution of horizontal passages, which are called *adits* when used for the conveyance of water near the surface, and *levels* when made for opening the *lode* or vein, and forming communications from one shaft to another under-ground. Levels ought to be seven feet in height, and two feet and a half wide; by constructing them as high as this, room is given to admit contrivances for ventilation, so that they may be continued to considerable lengths without inconvenience. More than two miners cannot work at one time on the end of a level, and the set of men therefore employed may consist of six, relieving every eight hours, or of four relieving twice in the twenty-four hours, or two men only, who may work as long as circumstances will permit. Driving is paid for by the fathom in length, the height and width being limited; a great variation of prices takes place according as the rock is hard or soft, as work of this sort is done from 10*s*. a fathom to £30, but about £5 a fathom is the most usual sum paid for this kind of work. These prices here, as well as in sinking shafts, include every expense, as the men pay for their tools, candles, and gunpowder, and likewise are charged with the wheeling the stuff, and hauling it to the surface.

Stoaping is that kind of work which is not included in sinking or driving, but more generally means the breaking away the ground between the levels on the course of the lode or vein, to get the ore. When the men work over head, it is called *stoaping the backs*, and when the work is carried downwards it is denominated *stoaping the bottoms*. As both these operations usually take place where ore is obtained, the mode of payment is quite different from that in sinking or driving, and is here called *tribute* work, while the other is called *tutwork*. *Tribute* means payment by a proportion of the produce, so that the men agree to undertake a particular piece of ground for a certain part of the value of the ore they may procure, when completely merchantable and fit for sale, every operation and process to make it so being conducted at their expense. This mode of contracting is of great advantage to the owners of the mine, as the men have a constant interest concurring with that of their employers, in discovering and procuring the greatest possible quantities of ore, and of returning it in the best and cheapest manner. The proportion paid to the miner, varies, of course, exceedingly, as many things must be taken into account in estimating a fair tribute for any particular part of a mine, but the contracts are made at so much out of every pound's worth sold, and this fluctuates often in different parts of the same mine from three-pence to fourteen shillings. Nothing shews the necessity of a mine being in the hands of skilful and honourable managers more than the great variation in the prices of all kinds of work carried on in these extensive undertakings.

We proceed to describe the parts of an engine-shaft, as they appear delineated in the annexed engraving (MINING, *Plate* II).

AAAA. *Timber-framing* put in to support the ground, where, from the rock not being sufficiently hard to stand securely, this precaution becomes necessary. Where boarding is required, the planks are driven perpendicularly between the transverse timber and the ground.

BBBB are *dividing-pieces*, or beams thrown cross the shaft. They serve to support the sides of the shaft, to attach the casing-boards to, which part off the whim-shaft from the foot-way and pump, or engine-shaft (it being usual to consider a large shaft of this kind as divided into the three kinds, each bearing its particular name). And, lastly, the dividing-pieces support the ends of the bearers which carry the pumps, ladders, &c.

CCCC. *Casing-boards* which part off the whim-shaft from the other parts: they are stout planks securely spiked to the dividing-pieces, and when the shaft is not perpendicular, the kibble slides upon them.

D. The *whim-kibble* which conveys up the ore and waste, two of which are employed in a shaft, one going up while the other goes down.

EF. *Ladders* for the workmen, forming what is usually called the foot-way.

G. *Saller*, a small platform at the foot of each ladder.

H. A column

H. A column of pumps drawing out of a cistern K, which is supplied by a lower tier of pumps I, furnished at the top with a *collar launder* J, which delivers into the cistern, which likewise receives the stream flowing from the level at L.

M, a *set off* which connects the *pump rods*, so that one set goes into the column I, and another is continued lower to a deeper lift of pumps.

NNNN, *bearers*, or timber beams, which support the pumps and keep them steady in their places.

The ventilation of mines is so important a subject that we insert at length the following account of a machine invented and applied to that purpose by Mr. Taylor, late the manager of the principal copper mines, in Devon; and for which he received the silver medal from the Society for the Encouragement of Arts, Manufactures, and Commerce.

"Next in importance to the means employed for draining underground works from water, may be reckoned those which are intended to afford a supply of pure air, sufficient to enable the workmen to continue their operations with ease and safety to themselves, and to keep up, undiminished, the artificial light upon which they depend. It is well known, indeed, to all who are practically engaged in concerns of this kind, that men are frequently obliged to persevere in their labour, where a candle will scarcely burn, and where not only their own health materially suffers in the end, but their employers are put to considerable additional expense by the unavoidable hinderance and the waste of candles and other materials.

"The following remarks are confined to such mines as are worked upon metalliferous veins, according to the practice of this district, and that of the great seat of mining in the neighbouring county of Cornwall, from which indeed ours is borrowed. We find then that a single shaft, not communicating by levels to another, can hardly be sunk to any considerable depth, nor can a level (or, as the foreign miners call it, a gallery) be driven horizontally to any great distance, without some contrivance for procuring currents of air to make up the deficiency of oxygen, which is so rapidly consumed by respiration and combustion in situations like these, where otherwise the whole remains in nearly a stagnant condition.

"We are here unacquainted with the rapid production of those gases which occasionally in the collieries are the cause of such dreadful effects; such as hydrogen gas, or the fire-damp, carbonic acid, or the choke-damp; the inconvenience we experience takes place gradually as we recede from the openings to the atmosphere, and seems to arise solely from the causes which have been before assigned, though it is found to come on more rapidly in certain situations than in others.

"The most obvious remedy, and that which is most frequently resorted to, is the opening a communication either to some other part of the mine, or to the surface itself; and as soon as this is done, the ventilation is found to be complete, by the currents which immediately take place, often with considerable force, from the different degrees of temperature in the subterranean and upper atmospheres; and these currents may be observed to change their directions as the temperatures alternate.

"The great objection to this mode of curing the evil is, the enormous expense with which it is most commonly attended. In driving a long level, or tunnel, for instance, it may happen to be at a great depth under the surface, and the intervening rock of great hardness; in such a case every shaft which must be sunk upon it for air alone, where not required (as often they might not) to draw up the waste, would cost several hundred pounds; or in sinking a shaft it may be necessary, at an expense not much less, to drive a level to it from some other for this purpose alone.

"To avoid this, recourse has been had to dividing the shaft or level into two distinct parts, communicating near the part intended to be ventilated, so that a current may be produced in opposite directions on each side the partition; and this, where room is to be spared for it, is often effectual to a certain extent. It is found, however, to have its limits at no very great distance, and the current at best is but a feeble one, from the nearly equal states of heat in the air on each side. The only scheme besides these has hitherto been to force down a volume of purer air, through a system of pipes placed for the purpose, and a variety of contrivances has been devised for effecting this; most of them are so old that they may be found described in Agricola's work *De Re Metallica*. The most common are by bellows worked by hand; by boxes or cylinders of various forms placed on the surface with a large opening against the wind, and a smaller one communicating with the air-pipes by a cylinder and piston working in it, which when driven by a sufficient force has great power. But the cheapest and most effectual scheme, for this purpose, where circumstances will admit of its being applied, is one which was adopted some time since in the tunnel of the Tavistock canal. It is by applying the fall of a stream of water for this purpose, and it has been long known that a blast of considerable strength may be obtained in this manner, which has the advantage of being constant and self-acting. The stream being turned down a perpendicular column of pipes, dashes in at a vessel so contrived as to let off the water one way, with an opening at another part for the air, which being pressed into it by the falling water, may be conveyed in any direction, and will pass through air-pipes with a strong current, which will be found efficacious in ventilating mines in many instances, as it has likewise, in some cases, been sufficient for urging the intensity of fires for the purposes of the forge. It is easily procured where a sufficient fall is to be had; and the perpendicular column can be so fixed as that the water from the bottom may pass off, while the air is forced into a pipe branching from the air-vessel, and which is to be continued to the part of the mine where the supply of fresh air is required.

"It

"It has been found, however, that the forcing into vitiated air a mixture of that which is purer, even when the best means are used, though a measure which affords relief, is not, in bad cases, a complete remedy; and, where the operation depends on manual labour, or any means that are not unremitted in their action, it becomes quite ineffectual. The foul air, charged with the smoke of gunpowder used in blasting, and which it strongly retains, is certainly meliorated by the mixture of pure air, but is not removed. While the blast continues, some of it is driven into the other parts of the mine; but when the influx of pure air ceases, it returns again: or if during the influx of pure air a fresh volume of smoke be produced by explosions, which are constantly taking place, it is not until some time afterwards that it becomes sufficiently attenuated for the workmen to resume their stations with comfort.

"A consideration of these circumstances led me to the supposition that the usual operation of ventilating engines ought to be reversed, to afford all the advantages that could be desired; that instead of using the machines which serve as condensers, exhausters should be adopted; and thus, instead of forcing pure air into that in a vitiated state, a complete remedy could only be had by pumping out all that was impure as fast as it became so.

"Many modes of doing this suggested themselves, by the alteration of the machines commonly applied, and by producing an ascending stream of air through pipes by a furnace constructed for the purpose. The latter mode would, however, have been here expensive in fuel as well as in attendance; and the others, required power to overcome the friction of pistons, and so on, or considerable accuracy in construction.

"At length the machine was erected of which the annexed is a drawing; which, while it is so simple in construction, and requires so small an expense of power, is so complete in its operation, and its parts are so little liable to be injured by wear, that nothing more can be desired where such an one is applied. This engine bears considerable resemblance to Mr. Pepys's gazometer, though this did not occur to the inventor until after it was put to work. It will readily be understood by an inspection of the engraving, *Pl.* III., where the shaft of the mine is represented at A; and it may here be observed, that the machine will be as well placed at the bottom of the shaft as at the top, and that in either case it is proper to fix it upon a floor, which may prevent the return of the foul air into the mine, after being discharged from the exhauster: this floor may be furnished with a trap-door, to be opened occasionally for the passage of buckets through it.

"B, the air-pipe from the mine passing through the bottom of the fixed vessel or cylinder C, which is formed of timber and bound with iron hoops; this is filled with water nearly to the top of the pipe B, on which is fixed a valve opening upwards at D.

"E, the air, or exhausting-cylinder made of cast-iron, open at the bottom and suspended over the air-pipe, immersed some way in the water. It is furnished with a wooden top, in which is an opening fitted with a valve likewise opening upwards at F.

"The exhausting-cylinder has its motion up and down given to it by the bob G, connected to any engine by the horizontal rod H, and the weight of the cylinder is balanced, if necessary, by the counterpoise I.

"The action is obvious.—When the exhausting-cylinder is raised, a vacuum would be produced, or rather the water would likewise be raised in it, were it not for the stream of air from the mine rushing through the pipe and valve D. As soon as the cylinder begins to descend, this valve closes, and prevents the return of the air which is discharged through the valve F.

"The quantity of air exhausted is calculated of course from the area of the bore of the cylinder, and the length of the stroke.

"The dimensions which have been found sufficient for large works, are as follow:—

"The bore of the exhausting-cylinder two feet.

"The length six feet, so as to afford a stroke of four feet.

"The pipes which conduct the air to such an engine ought not to be less than six-inch bore.

"The best rate of working is from two to three strokes a minute; but if required to go much faster, it will be proper to adapt a capacious air-vessel to the pipes near the machine, which will equalize the current pressing through them.

"Such an engine discharges more than two hundred gallons of air in a minute; and I have found that a stream of water supplied by an inch and a half bore falling twelve feet, is sufficient to keep it regularly working.

"A small engine to pump out two gallons at a stroke, which would be sufficient in many cases, could be worked by a power equal to raising a very few pounds weight, as the whole machine may be put into complete equilibrium before it begins to work, and there is hardly any other friction to overcome but that of the air passing through the pipes.

"The end of the tunnel of the Tavistock canal, which it was my object to ventilate, was driven into the hill to a distance of nearly three hundred yards from any opening to the surface; and being at a depth of one hundred and twenty yards, and all in hard schistus rock, air-shafts would have been attended with an enormous expense; so that the tunnel being a long one, it was most desirable to sink as few as possible, and, of course, at considerable distances from each other. Thus a ventilating machine was required, which should act with sufficient force through a length of nearly half a mile; and on the side of the hill where it first became necessary to apply it, no larger stream of water to give it motion could be relied on, than such an one as is mentioned after the description of the engine, and even that flowed at a distance from the shaft where the engine was to be fixed; which made a considerable length of connexion-rods necessary.

"Within a very short time after the engine began to work, the superiority of its action over those formerly employed was abundantly evident. The whole extent of the tunnel, which had been uninterruptedly clouded with smoke for some months before, and which the air that was forced in never could drive out, now became speedily so clear, that the day-light and even objects at its mouth were distinctly seen from its furthest end. After blowing up the rock, the miners could instantly return to the place where they were employed, unimpeded by the smoke, of which no appearance would remain under-ground in a very few minutes, while it might be seen to be discharged in gusts, from the valve at the top of the shaft. The constant current into the pipe, at the same time effectually prevented the accumulation of air unfit for respiration. The influx of air, from the level into the mouth of the pipe, rushes with such force as instantly to extinguish the flame of a large candle; and any substance applied, so as to stop the orifice, is held tight by the outward pressure.

"It is now more than two years since the machine was erected, and it has been uninterruptedly at work ever since, and without repair. The length of the tunnel has been nearly doubled, and the pipes, of course, in the same proportion, and no want of ventilation is yet perceptible.

"Two similar engines have been since constructed for other parts of the same tunnel, and have in every respect answered the purpose for which they were designed.

"The original one is worked by the small stream of water before-mentioned, by means of a light overshot-wheel twelve feet in diameter, and about six inches in breast.—The two others are attached to the great overshot-wheel which pumps the water from the shafts which are sinking upon the line; and as their friction is comparatively nothing, this may be done in any case, with so little waste of power for this purpose as not to be an object of consideration, even if the power be derived from more expensive means.

"The size of the exhauster may always be proportioned to the demand for air; and by a due consideration of this circumstance, this engine may be effectually adapted not only to mines and collieries, but also to manufactories, work-houses, hospitals, prisons, ships, and so on.

"Thus, if it were required to ventilate a shaft of a mine, or a single level, which is most frequently the case, where three men are at work at one time, and we allow that those three men vitiate each twenty-seven and a half cubic inches of air per minute (as determined by the experiments of Messrs. Allen and Pepys), and allowing further that their candles vitiate as much as the men, there will be six times twenty-seven and a half cubic inches of air to be drawn out in a minute, equal to one hundred and sixty-five.

"Now a cylinder five inches in diameter, working with a stroke at nine inches, will effect this by one stroke in a minute; though it would certainly be advisable to make it larger.

"Not being practically acquainted with collieries, or mines that suffer from peculiar gases that are produced in them, I cannot state, from actual experiment, what effect this machine might have in relieving them; but it must appear evident to every person at all acquainted with the first principles of pneumatics, that it must do all that can be wished, as it is obvious that such a machine must in a given time pump out the whole volume of air contained in a given space, and thus change an impure atmosphere for a better one. And in constructing the machine it is only necessary to estimate the volume of gas produced in a certain time, or the capacity of the whole space to be ventilated. It is easy to judge how much more this must do for such cases as these, than such schemes as have lately been proposed of exciting jets of water, or slaking lime, both of which projects, likewise, must fail when applied; as one of them has when applied to the case of hydrogen gas. But with such a machine as this, if the dreadful effects of explosions of this air are to be counteracted, it may be done by one of sufficient size to draw off the air as fast as it is generated; and by carrying the pipes into the elevated parts of the mine, where from its lightness it would collect. If, on the other hand, it is desired to free any subterraneous work from the carbonic acid gas, it may as certainly be done by suffering the pipe to terminate in the lower parts, where this air would be directed by its gravity.

"In workhouses, hospitals, manufactories, &c., it is always easy to calculate the quantity of air contained in any room, or number of rooms, and easy to estimate how often it is desirable to change this in a certain number of hours, and to adjust the size and velocity of the engine accordingly. Where this change of foul air for pure is to take place in the night, means for working the machine may be provided by pumping up a quantity of water into a reservoir of sufficient height to admit of its flowing out during the night in a small stream, with sufficient fall, so as to give motion to the engine; or by winding up a weight of sufficient size, or by many other means which are easily devised.

"If, for instance, a room in which fifty persons slept was eighty feet long, twenty wide, and ten high, it would contain 16,000 cubic feet of air, and if this was to be removed twice in eight hours, it would require a cylinder of thirty inches diameter, working with a four-feet stroke four times in a minute, to do it; or nearly that. Such a cylinder could be worked by the descent of ten gallons of water ten feet in a minute; or, for the whole time, by eighty hogsheads falling the same height.

"But this is a vast deal more than could be required, as the fifty people would in eight hours vitiate only three thousand gallons of air, which could be removed by one hundred and fifty strokes of a cylinder, twelve inches diameter, with a four feet stroke, which would not require an expenditure of more than one thousand five hundred gallons of water properly applied, or about twenty-eight hogsheads."

MODELLING.

MODELLING.

Models, in imitation of any natural or artificial substance, are most usually made by means of moulds, composed of plaster of Paris. For the purpose of making these moulds, this kind of plaster is more fit than any other substance, on account of the power it has of absorbing water, and quickly condensing into a hard substance, even after it has been rendered so thin as to be of the consistence of cream. It is sold in the shops at different prices; the finest being made use of for casts, and the middling sort for moulds. It may be very easily coloured by means of almost any kind of powder excepting what contains an alkaline salt; for this would chemically decompose it, and render it unfit for use. A very considerable quantity of chalk would also render it soft and useless, but lime hardens it to a great degree. The addition of common size will render it much harder than if mere water is made use of. In making either moulds or models, we must be careful not to make the mixture too thick at first; for if this is done, and more water added to thin it, the composition will always prove brittle and of a bad quality.

The particular manner of making models depends on the form of the subject to be taken. The process is easy, where the parts are elevated only in a slight degree, or where they form only a right or obtuse angle with the principal surface from which they project; but where the parts project in smaller angles, or from curves inclined towards the principal surface, the work is more difficult. This observation, however, holds good only with regard to hard and inflexible bodies.

The moulds are to be made of various degrees of thickness, according to the size of the model to be cast; and may be from half an inch to an inch, or, if very large, an inch and an half. Where a number of models are to be taken from one mould, it will likewise be necessary to have it of a stronger contexture than where only a few are required, for very obvious reasons. When a model is to be taken, the surface of the original is first to be greased, in order to prevent the plaster from sticking to it; but if the substance itself is slippery, as is the case with the internal parts of the human body, this need not be done: when necessary, it may be laid over with linseed oil by means of a painter's brush. The original is then to be laid on a smooth table, previously greased or covered with a cloth, to prevent the plaster sticking to it; then surround the original with a frame or ridge of glaziers' putty, at such a distance from it as will admit the plaster to rest upon the table on all sides of the subject for about an inch, or as much as is sufficient to give the proper degree of strength to the mould. A sufficient quantity of plaster is then to be poured as uniformly as possible over the whole substance, until it be every where covered to such a thickness as to give a proper substance to the mould, which may vary in proportion to the size. The whole must then be suffered to remain in this condition till the plaster has attained its hardness; when the frame is taken away, the mould may be inverted, and the subject removed from it; and when the plaster is thoroughly dry let it be well seasoned.

Having formed and seasoned the moulds, they must next be prepared for the casts by greasing the inside of them with a mixture of olive-oil and lard in equal parts, and then filled with fine fluid plaster, and the plane of the mould formed by its resting on the surface of the table covered to a sufficient thickness with coarse plaster, to form a strong basis or support for the cast where this support is requisite, as is particularly the case where the thin and membranous parts of the body are to be represented. After the plaster is poured into the mould, it must be suffered to stand until it has acquired the greatest degree of hardness it will receive; after which the mould must be removed: but this will be attended with some difficulty when the shape of the subject is unfavourable; and in some cases the mould must be separated by means of a small mallet and chisel. If, by these instruments, any parts of the model should be broken off, they may be cemented by making the two surfaces to be applied to each other quite wet, then interposing betwixt them a little liquid plaster; and, lastly, the joint smoothed after being thoroughly dry. Any small holes that may be made in the mould can be filled up with liquid plaster, after the sides of them have been thoroughly wetted, and smoothed over with the edge of a knife.

Besides models which are taken from inanimate bodies, it is often necessary to take the exact resemblance of people while living, by using the face itself as a model, from whence to take a mould. The operation is, undoubtedly, disagreeable, yet it is what many persons of the highest rank have submitted to. There is also some danger unless the operator understands his business well. It may, however, be performed without the smallest risque, and in a few minutes, by those who are conversant with modelling. The person from whom the cast is to be taken is to be laid horizontally on his back, with the head raised to the exact position in which it is naturally carried when the body is erect; then the parts to be represented must be covered over with

with oil of almonds, after which the face is then to be covered with fine fluid plaster, beginning at the upper part of the forehead, and spreading it over the eyes, which are to be kept close, yet not closed so strongly as to cause any unnatural wrinkles. Cover then the nose and ears, taking care to plug up first the "meatus auditorii" with cotton, and the nostrils with a small quantity of tow rolled up, of a proper size, to exclude the plaster. During the time the nose is thus stopped, the person is to breathe through the mouth; and in this state the fluid plaster is to be brought down low enough to cover the upper lip, observing to leave the rolls of tow projecting out of the plaster. When this becomes sufficiently hard, the tow may be withdrawn, and the nostrils left free and open for breathing. The mouth is then to be closed in its natural position, and the plaster brought to the extremity of the chin. Begin then to cover that part of the breast which is to be represented, and spread the plaster to the outsides of the arms and upwards, in such a manner as to meet and join that which is previously laid on the face: when the whole mass has acquired its due hardness, it is to be cautiously lifted up and removed. After this, the mould is to be seasoned, and it is fit for casting of models. In the model, the eyes, that are necessarily shown closed, are to be carved, so that the eyelids may be represented in an elevated posture, the nostrils hollowed out, and the back part of the head, from which, on account of the hair, no mould can be taken, must be finished according to the skill of the artist. The edges of the model are then to be neatly smoothed off, and the bust fixed on its pedestal.

We shall now give some account of modelling as it refers to sculpture. As not only the beginning of sculpture was in clay, for the purpose of forming statues, but as models are still made in clay or wax, for every work undertaken by the sculptor; we shall first consider the method of modelling figures in clay or wax.

Few tools are necessary for modelling in clay. The clay being placed on a stand, or sculptor's easel, the artist begins the work with his hands, and puts the whole into form by the same means. The most expert practitioners of this art seldom use any other tool than their fingers, except in such small or sharp parts of their work as the fingers cannot reach. For these occasions they are provided with three or four small tools of wood, about seven or eight inches in length, which are rounded at one end, and, at the other they are flat, and shaped into a sort of claws. These tools are called, by the French, ebauchoirs. In some of these the claws are smooth, for the purpose of smoothing the surface of the model; and, in others, they are made with teeth, to rake or scratch the clay, which is the first process of the tool on the work, and in which state many parts of the model are frequently left by artists, to give an appearance of freedom and skill to their work.

If clay could be made to preserve its original moisture, it would undoubtedly be the fittest substance for the models of the sculptor; but when it is placed either in the fire, or left to dry imperceptibly in the air, its solid parts grow more compact, and the work shrinks, or loses a part of its dimensions. This diminution in size would be of no consequence, if it affected the whole work equally, so as to preserve its proportions. But this is not always the case, for the smaller parts of the figure drying sooner than the larger, and thus losing more of their dimensions in the same space of time than the latter do, the symmetry and proportions of the work inevitably suffer.

This inconvenience, however, is obviated by forming the model first in clay, and moulding it in plaster of Paris before it begins to dry, and the taking a plaster cast from that mould, and the repairing it carefully from the original work; by which means you have the exact counterpart of the model in its most perfect state; and you have, besides, your clay at liberty for any other work.

In order to model in wax, you must prepare the wax in the following manner:—To a pound of wax add half a pound of scammony (some mix turpentine also), and melt the whole together with oil of olives; putting more or less oil as you would have your modelling-wax harder or softer. Vermilion is sometimes mixed with this composition, to give it a reddish colour, in imitation of flesh.

In modelling in wax, the artist sometimes uses his fingers, and sometimes tools of the same sort as those described for modelling in clay. It is at first more difficult to model in wax than in clay, but practice will render it familiar and easy.

Of the Use of the Model.—Whatever considerable work is undertaken by the sculptor, whether bas-relief, or statue, &c., it is always requisite to form a previous model of the same size as the intended work; and the model being perfected, according to the method before described, whether it is in clay, or in wax, or a cast in plaster of Paris, becomes the rule, whereby the artist guides himself in the conduct of his work, and the standard from which he takes all its measurements. In order to regulate himself more correctly by it, he puts over the head of the model an immovable circle, divided into degrees, with a movable rule fastened in the centre of the circle, and likewise divided into parts. From the extremity of the rule hangs a line with a lead, which directs him in taking all the points which are to be transferred from the model to the marble; and from the top of the marble is hung also a line, tallying with that which is hung from the model; by the correspondence of which two lines the points are ascertained in the marble.

Many eminent sculptors prefer measurements taken by the compasses to the method just described; for this reason, that if the model is moved but ever so little from its level, the points are no longer the same.

This method, however, offers the best means, by which mechanical precision may be attained; but it is manifest, that enough yet remains to exercise and display

play the genius and skill of the artist. For, first, as it is impossible, by the means of a straight line, to determine with precision the procedure of a curve, the artist derives from this method no certain rule to guide him as often as the line which he is to describe deviates from the direction of the plumb-line. It is also evident, that this method affords no certain rule to determine exactly the proportion which the various parts of the figure ought to bear to each other, considered in their mutual relation and connexions. This defect, indeed, may be partly supplied by intersecting the plumb-lines by horizontal ones; but even this resource has its inconveniences, since the squares formed by transversal lines that are at a distance from the figure (though they are exactly equal), yet represent the parts of the figure as greater or smaller, according as they are more or less removed from one point of view.

The method of making models in plaster of Paris is undoubtedly the most easy way of obtaining them. When models, however, are made of such large objects that the model itself must be of considerable size, it is in vain to attempt making it in the way above described. Such models must be constructed by the hand with some soft substance, as wax, clay, putty, &c., and it being necessary to keep all the proportions with mathematical exactness, the construction of a single model of this kind must be a work of great labour and expense, as well as of time. Of all those which have been undertaken by human industry, however, perhaps the most remarkable is that constructed by General Pfeiffer, to represent the mountainous parts of Switzerland. It is composed of one hundred and forty-two compartments, of different sizes and forms, respectively numbered, and so artfully put together, that they can be separated and replaced with the greatest ease. The model itself is twenty feet and a half long, and twelve broad, and formed on a scale which represents two English miles and a quarter by an English foot; comprehending part of the cantons of Zug, Zurich, Schweitz, Underwalden, Lucerne, Berne, and a small part of the mountains of Glarus; in all, an extent of country of eighteen leagues and a half in length, and twelve in breadth. The highest point of the model, from the level of the centre (which is the lake of Lucerne), is about ten inches: and as the most elevated mountain represented therein rises 1,475 toises, or 9,440 feet, above the lake of Lucerne, at a gross calculation, the height of an inch in the model is about 900 feet. The whole is painted of different colours, in such a manner as to represent objects as they exist in nature; and so exactly is this done, that not only the woods of oak, beech, pine, and other trees, are distinguished, but even the strata of the several rocks are marked, each being shaped upon the spot, and formed of granite, gravel, or such other substances as compose the natural mountain. So minute also is the accuracy of the plan, that it comprises not only all the mountains, lakes, rivers, towns, villages, and forests, but every cottage, bridge, torrent, road, and even every path is distinctly marked.

The principal material employed in the construction of this extraordinary model, is a mixture of charcoal, lime, clay, a little pitch, with a thin coat of wax; and it is so hard that it may be trod upon without any damage. It was begun in the year 1766, at which time the General was about fifty years of age, and it employed him till the month of August 1785; during all which long space of time he was employed in the most laborious and even dangerous tasks. He raised the plans with his own hands on the spot, took the elevation of mountains, and laid them down in their several proportions. In the prosecution of this laborious employment, he was twice arrested for a spy; and in the popular cantons was frequently forced to work by moon-light, in order to avoid the jealousy of the peasants, who imagined that their liberty would be endangered should a plan of their country be taken with such minute exactness. Being obliged frequently to remain on the tops of some of the Alps, where no provisions could be procured, he took along with him a few milch goats, who supplied him with nourishment. When any part was finished, he sent for the people residing near the spot, and desired them to examine each mountain with accuracy, whether it corresponded, as far as the smallness of the scale would admit, with its natural appearance; and then, by frequently retouching, corrected the deficiencies. Even after the model was finished, he continued his Alpine expeditions with the same ardour as ever, and with a degree of vigour that would have fatigued a much younger person. All his elevations were taken from the level of the lake Lucerne; which, according to M. Saussure, is 1,408 feet above the level of the Mediterranean.

To take a cast in metal from any small animal, insect, or vegetable.—Prepare a box of four boards, sufficiently large to hold the animal, in which it must be suspended by a string, and the legs, wings, &c. of the animal, or the tendrils, leaves, &c. of the vegetable, must be separated, and adjusted in their right position by a pair of small pincers. A due quantity of plaster of Paris mixed with talc, must be tempered to the proper consistence with water, and the sides of the box oiled. Also a straight piece of stick must be put to the principal part of the body, and pieces of wire to the extremities of the other parts, in order that they may form, when drawn out after the matter of the mould is set and firm, proper channels for pouring in the metal, and vents for the air, which otherwise, by the rarefaction it would undergo from the heat of the metals, would blow it out, or burst the mould. In a short time the plaster will set, and become hard, when the stick and wires may be drawn out, and the frame or coffin in which the mould was cast taken away; and the mould must then be put, first, into a moderate heat, and, afterwards, when it is as dry as can be rendered by that degree, removed into a greater, which may be gradually increased, till the

 whole

whole be red hot. The animal or vegetable enclosed in the mould, will then be burnt to a coal; and may be totally calcined to ashes, by blowing for some time into the charcoal and passages made for pouring in the metal, and giving vent to the air, which will at the same time that it destroys the remainder of the animal or vegetable matter, blow out the ashes. The mould must then be suffered to cool gently, and will be perfect, the destruction of the substance included in it having produced a corresponding hollow; but it may nevertheless be proper to shake the mould, and turn it upside down, as also to blow with the bellows into each of the air-vents, in order to free it wholly from any remainder of the ashes; or where there may be an opportunity of filling the hollow with quicksilver, it will be found a very effectual method of clearing the cavity, as all dust, ashes, or small detached bodies, will necessarily rise to the surface of the quicksilver, and be poured out with it. The mould being thus prepared, it must be heated very hot, when used, if the cast is to be made with copper or brass, but a less degree will serve for lead or tin. The metal being poured into the mould, must be gently struck, and then suffered to rest till it be cold; at which time it must be carefully taken from the cast, but without the force: for such parts of the matter as appear to adhere more strongly, must be softened, by soaking in water till they be entirely loosened, that none of the more delicate parts of the cast may be broken off or bent.

When talc cannot be obtained, plaster alone may be used; but it is apt to be calcined, by the heat used in burning the animal or vegetable from whence the cast is taken, and to become of too incoherent and friable a texture. Stourbridge, or any other good clay, washed perfectly fine, and mixed with an equal part of fine sand, may be employed. Pounded pumice-stone, and plaster of Paris, in equal quantities, mixed with washed clay in the same proportion, is said to make excellent moulds.

To take Casts from Medals.—In order to take copies of medals, a mould must first be made; this is generally either of plaster of Paris, or of melted sulphur.

After having oiled the surface of the medal with a little cotton, or a camel's-hair pencil dipped in oil of olives, put a hoop of paper round it, standing up above the surface of the thickness you wish the mould to be. Then take some plaster of Paris, mix it with water to the consistence of cream, and with a brush rub it over the surface of the medal, to prevent air-holes from appearing; then immediately afterwards make it to a sufficient thickness, by pouring on more plaster. Let it stand about half an hour, and it will in that time grow so hard, that you may safely take it off; then pare it smooth on the back and round the edges neatly. It should be dried, if in cold or damp weather, before a brisk fire. If you cover the face of the mould with fine plaster, a coarser sort will do for the back: but no more plaster should be mixed up at one time than can be used, as it will soon get hard, and cannot be softened without burning over again.

Sulphur must not be poured upon silver medals, as this will tarnish them.

To prepare this mould for casting sulphur or plaster of Paris in, take half a pint of boiled linseed-oil, and oil of turpentine one ounce, and mix them together in a bottle; when wanted, pour the mixture into a plate or saucer, and dip the surface of the mould into it; take the mould out again, and when it has sucked in the oil, dip it again. Repeat this, till the oil begins to stagnate upon it; then take a little cotton wool, hard rolled up, to prevent the oil from sticking to it, and wipe it carefully off. Lay it in a dry place for a day or two (if longer the better), and the mould will acquire a very hard surface from the effect of the oil.

To cast plaster of Paris in this mould, proceed with it in the same manner as above directed for obtaining the mould itself, first oiling the mould with olive-oil. If sulphur casts are required, it must be melted in an iron ladle.

Another method with isinglass.—Dissolve isinglass in water over the fire; then, with a hair-pencil, lay the melted isinglass over the medal; and when you have covered it properly let it dry. When it is hard, raise the isinglass up with the point of a penknife, and it will fly off like horn, having a sharp impression of the medal.

The isinglass may be made of any colour, by mixing the colour with it; or you may breathe on the concave side, and lay gold leaf on it, which, by shining through, will make it appear like a gold medal. But if you wish to imitate a copper medal, mix a little carmine with the isinglass, and lay gold leaf on as before.

To colour Plaster.—Plaster of Paris may be tinged with several colours, when you are casting, by mixing it with Prussian blue, red lead, or yellow ochre, with which you may compose a blue, red, yellow, and green. As the coloured plaster takes a little more time to dry than when it is unmixed, you may sift some dry plaster upon the back of the casts when in the mould, which will make them dry quicker.

It will not be deemed irrelevant to this subject to notice M. Lenormand's account of his art of moulding carving in wood. It was published a few years since in the "Bibliotheque Physico-Economique;" he was led to the invention through that sort of necessity which results from the want of good carvers. He had seen plasterers supply the want of good modellers by incrusting in their decoratings plaster moulded on excellent models; he therefore conceived that it might be possible to mould carving in wood, to be afterwards applied to cabinet-makers' work. He was aware that very hard wood, such as box, might be moulded by putting it under a press in copper moulds, after having subjected it to certain preparations, but for this purpose very expensive moulds, an excellent press, &c. are required, which occasions considerable expense, and by this method bas-reliefs only can be executed; but the

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art, which Lenormand calls his own, requires only cheap materials with very little practice, and affords the means of making not only figures in relief, but even the most difficult objects in sculpture. The following is the process as described by the inventor.

"I made very clear glue with five parts of Flanders' glue and one part of fish-glue, or isinglass. I dissolved these two kinds of glue separately in a large quantity of water, and mixed them together after they had been strained through a piece of fine linen to separate the filth and heterogeneous parts which could not be dissolved. The quantity of water cannot be fixed, because all kinds of glue are not homogeneous, so that some require more and some less. The proper degree of liquidity may be known by suffering the mixed glue to become perfectly cold; it must then form a jelly, or rather a commencement of jelly. If it happens that it is still liquid when cold, a little of the water must be evaporated by exposing the vessel in which it is contained to heat. On the other hand, if it has too much consistence, a little warm water must be added. In a word, the proper degree will be ascertained by a few trials.

"The glue, thus prepared, is to be heated till you can scarcely endure your finger in it; by this operation a little water is evaporated, and the glue acquires more consistence. Then take fine raspings of wood, or saw-dust, sifted through a fine hair-sieve, and form it into a paste, which must be put into moulds of plaster or sulphur after they have been well rubbed over with linseed or nut-oil, in the same manner as when plaster is to be moulded. Care must be taken to press the paste in the mould with your hand, in order that it may acquire all the forms of the mould: then cover it with an oiled board, and, placing over it a weight, suffer it in that manner to dry. The desiccation may be hastened and rendered more complete by a stove. When the impression is dry, remove the rough part, and if any inequalities remain behind they must be smoothed: after which the impression may be affixed with glue to the article for which it is intended. Then cover it with a few strata of spirit of wine varnish, as is done in general in regard to carved work, or with wax in the encaustic manner. It requires much attention to discover that such ornaments are not carved in the usual manner. Gilding may be applied to them with great facility. This operation is exceedingly easy; nothing is necessary but moulds; and, with a little art, the ornaments may be infinitely varied.

"I tried also to mould figures, and completely succeeded. These, however, require more care. I first make a paste, similar to the former, with very fine saw-dust, and place a stratum, of about two lines in thickness, on every part of the mould; after which it is left to dry almost entirely. In the mean time, I prepare a coarse paste with coarse saw-dust which has not been made to pass through a fine but a coarse sieve, and instead of Flanders' glue I employ common glue, which is less expensive, adding to it a sixth of fish glue. I first put together two parts of the mould, after introducing into the joints a slight stratum of the fine paste, which I make very clear, and apply with a small brush. I fill up the vacuity between the two pieces with coarse paste. I then apply the third piece as I did the second, and so on until the whole are adjusted, always filling up the vacuities with coarse paste. I suffer the whole to dry in the mould, and obtain a figure in relief of solid wood executed with all the delicacy of plaster figures. Care must be taken to remove with a sharp knife, or small file, the prominences formed by the joinings. If the figure be not suffered to dry too much, these prominences may be easily removed with the point of a sharp penknife. It will be necessary to learn the art of determining the proper degree of desiccation; for if the figure be taken from the mould before it is properly dried it will become warped, and if it be too dry, it cannot be corrected but with a file, which is tedious and laborious, whereas, if the proper moment be seized, the paste may be cut like wax; especially if the saw-dust has been fine, which is necessary for the exterior strata. The figures may then be completely dried in a stove, by which means they will acquire a degree of desiccation and solidity hardly to be conceived. Figures thus moulded may be bronzed or varnished: they will then be unalterable by the effects of moisture or dryness.

"I have already said, that Flanders, and not common glue, ought to be employed for the exterior strata, because this glue is almost colourless. When this cannot be had, a glue fit for the purpose may be made by boiling shreds of parchment in common water till dissolved: whereas the other, being dark-coloured, gives too obscure a tint even to walnut-tree wood. Being desirous to try whether my moulded figures would be unalterable by the effects of moisture or dryness, I made the following experiments:—

"Experiment I.—I exposed, in a large bell-glass filled with atmospheric air, two figures, one of which was varnished and the other not. I placed under the bell Saussure's hygrometer, and a capsule filled with water, after having moistened the sides of the bell. The air was soon saturated with water, and the hygrometer marked 100 degrees. I observed no alteration whatever in the varnished figure, and the other exhibited no other sensible alteration than a commencement of solution in the glue, so that on applying my finger to its surface it was found to be somewhat viscid; in a word, the figure was not in the least warped.

"Experiment II.—I then introduced my two figures and the hygrometer into another very dry bell, under which I placed a capsule filled with calcined pot-ash. The moisture of the air by which the figures were surrounded was soon absorbed, and the hygrometer indicated zero. In order to ascertain whether the whole moisture imbibed by the unvarnished figure was entirely dissipated, I left every thing in statu quo for four hours, the hygrometer still indicating zero. I then took out the two figures, neither of which had experienced the least alteration.

"Experiment

"Experiment III.—I repeated the first experiment with a view to cause the two figures to absorb as much moisture as possible; and when the hygrometer marked 100° I took them from the bell, and suddenly introduced them into a stove, the heat of which was 50° of Reaumür. The unvarnished one became dry without cracking, and the other showed a little softening in the varnish. This effect I ascribed to the imperfect desiccation before the experiment, for the softening was more considerable than is generally the case when a varnished body is exposed to heat.

"These experiments appeared to me sufficient to induce me to conclude, that sculpture in moulded wood, according to the process here described, is unalterable by moisture or drought, for in our climates the thermometer never rises to 50°. Such sculptured figures have the solidity of wood, and are even preferable to it; for a slight blow given to wood, if cut across the fibres, will detach some of the parts; whereas figures formed of artificial wood, if I may be allowed the expression, are homogeneous in all their parts, and are not so easily broken.

"Besides the advantages which this invention on the first view exhibits, it offers others which may be of great utility to our arts and manufactures. 1st. In the large manufactories of mirrors, the ornaments in general are in a very bad taste, and miserably executed, because the carvers are very ill paid. If this new method be adopted, sculptors would pay more attention to their first work; they would mould their ornaments in plaster or in sulphur, then take a multitude of copies with the greatest facility, and these ornaments would add to the value of our furniture. 2d. Inlayers would make much more elegant works by employing pastes of different coloured woods, which might be managed with greater ease than the thin pieces of coloured boards which they employ."

MUSICAL INSTRUMENT MAKING.

THIS business requires the aid of a number of other mechanics. The joiner, turner, cabinet-maker, wire-drawer, &c. have all their share in the manufacture of musical instruments of the different kinds; it may therefore be more interesting to our readers to give an idea of the construction of several of the more common instruments, than pretend to lay down rules for putting the instruments together.

Musical instruments have been arranged, according as they are calculated for exciting sound by the vibrations of the air, or by the joint effects of the air and a solid body vibrating together. The main varieties of stringed instruments are found in the harp, the piano-forte, the guitar, the violin, and the Æolian harp. In these, and in others of a similar construction, the force of the sound of the strings is increased by means of a sounding-board, which appears agitated by their motion, and to act with greater effect, and more powerfully on the air than the strings could do alone. In the *harp* the sound is produced by inflecting the string with the finger, and then permitting it to return to its place. It is imagined, that the lyre of the ancients differed from the modern harp chiefly in its form and compass, except that the performer sometimes used a plectrum, which was a small instrument made of ivory, or some other substance, for striking the strings. Each note in the harp has a separate string: in the Welsh harp, which is not much used in England, there are two strings to each note of the principal scale, with an intermediate row for the semi-tones. In the pedal harp, the half-notes are formed by pressing pins against the strings, so as to shorten their effective length. Instead of this method, we have heard that an attempt was some years since made to produce the semi-tones by changing the tension of the strings.

In the harpsichord, and in the spinnet, which is, in fact, but a small harpsichord, the quill acts like the finger in the harp, or the plectrum in the lyre, and it is fixed to the jack by a joint with a spring, allowing it, without difficulty, to repass the string, which is metallic. In some cases, leather is used instead of quills, which is intended to render the tone more mellow, and, of course, less powerful. Besides two strings in unison for each note, the harpsichord has generally a third, which is an octave above them. There are various means adopted to produce different modifications of the tone, as striking the wire in different parts, or by bringing soft leather loosely into contact with its fixed extremity. When the finger is removed from the key a damper of cloth falls on the string, and destroys its motion. In all instruments of this kind, the perfection of the tone depends much on the sounding-board: it is usually made of thin deal wood, strengthened at different parts by thicker pieces fixed below it.

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In the *piano-forte* the sound is produced by a blow of a hammer raised by a lever, which is as much detached from it as possible. The dulcimer of the Germans is also made to sound by the percussion of hammers held in the hand of the performer. The grand piano-forte resembles the harpsichord in form, but its action and tone are much superior. Its wires run longitudinally along the belly, or sounding-board, supported at about two-thirds of an inch distance by small low curved battens of beech, or other wood, on which are pins firmly driven into the battens, for the purpose of keeping the wires perfectly parallel. These battens, called bridges, determine the lengths of the several wires; though the latter pass beyond them for some distance, being looped on at their farther ends to stout pins driven into a solid part of the frame-work, and coming over the bridge which is next to the keys, with which it is parallel, and winding on a set of iron pegs, which being driven into a solid block of hard wood, are turned either right or left by means of a small instrument called a tuning-hammer, and are thus tightened or relaxed at pleasure. The shortest wires are the thinnest, which lie to the right, and give the upper notes. The longest are to the left, and give the lowest notes; those between them are longer or shorter according to their situation; their several lengths increasing as they approach towards the left side of the instrument; forming, by means of the bridges, which lay obliquely, a triangular figure. Each note has three wires, lying within somewhat less than half an inch in breadth: these are equidistant, and proceed to three rows of tuning-pins, so that the tuner cannot mistake as to which of the three wires he acts upon. The wires are imported from Germany, our artisans not having acquired the mode of giving them a due degree of temper. We understand, a noble Earl is making experiments on different kinds of wire, in hopes of rivalling or surpassing that of foreign manufacture. Those of the higher notes are of brass, and commonly begin with No. 8, 9, or 10, gradually increasing in thickness until they reach the extent of about four octaves, when they give place to copper wires, which produce a deeper sound.

The wires of the piano are made, as we have observed, to sound by means of wooden levers, called hammers, each of which has a rising projection at its end, covered with folds of leather, so as to produce a clear tone. These hammers are impelled upwards by means of the keys, which being depressed by the fingers, and balancing on small battens, on which they are arranged and kept steady by strong pins passing through near the points of equilibrium, also having little knobs of pump-leather standing on stems of wire at their inner ends, cause the levers to rise on the least touch of the finger, with a smart stroke, so as to touch the three wires of their respective notes. The levers being fixed to a frame, parallel with the keys, by means of vellum hinges, return to their places, and lay on a small parallel apron covered with baize, so that no rattling nor gingling results from their retrocession. These hammers may be distinctly seen when working, as they pass through a broad slit made in the sounding-board, the whole breadth of the instrument. At the inner extremities of the keys are small pieces of buff-leather, which take off the sound that would else proceed from their contact with the shafts of the dampers; which are contrivances for stopping the tones of such wires as are struck by the hammers, so soon as the finger is taken off from the key.

Most grand piano-fortes have two pedals, one for each foot, communicating with the interior. One serves to raise all the dampers completely, the other to throw the whole of the key-frame to the right, more or less; by this means the hammers are slid at the same moment, in a body, about a quarter of an inch to the right, so as to quit either one or two, at pleasure, of the left-hand wires of each note, and to strike upon only one, or two, as is judged proper for the greater or less diminution of sound. Other pedals are sometimes affixed for the purpose of opening a kind of flat cover, like Venetian blinds, laying over the wires, thereby to allow more or less sound to pass. The sounding-board, or belly, is made of very fine narrow deals, chiefly imported from the Continent, so closely joined that, in many, no line, or indication of junction, can be distinguished.

The square piano-forte is very different in form from the grand. It, however, has an action, or movements, nearly similar. Its belly is short, and the bridge, or sounding-board, is rather curved. In some, the tuning-pegs, which are four in a line, form a kind of column on the right; in others, they are immediately beyond that bridge which is almost parallel with the keys. Each note has two wires; those in alt, and, indeed, down to G, on the clef-line, are usually steel, from No. 8 to 12; the middle notes have brass wire; about half an octave of the bass parts are furnished with copper; and the eight or ten lowest notes are of brass wire, on which a thinner wire of the same metal is wound in an open spiral manner; whereby a deep tone is produced. Square piano-fortes are made with pedals, but not for sliding the keys and removing the hammers laterally. That could not be done to any purpose in this instrument; as the wires, instead of receding from the player in a perpendicular line with the keys, lie across at nearly right angles. One pedal is all that is necessary, namely, to raise the dampers while tuning.

The piano-forte is of German origin, and derives its name from its equal command both of softness and strength of tone. The chief beauty of this instrument, and which indeed constitutes its principal excellence over the harpsichord, is its capacity of obeying the touch, so as to enable the performer to vary and accommodate the expression to all those delicacies, energies, and striking lights and shades which characterize the most refined compositions. This instrument, though of modern invention, has received many useful and

valuable improvements from the ingenuity of Englishmen, as well as of foreigners. In that state, in which we have described it as the grand piano-forte, and in which it is furnished with its additional keys, it is not only qualified to give brilliancy and effect to sonatas, concertos, and all pieces of extraordinary execution, but forms an expressive accompaniment to the voice, and is thought, by the best judges, to be one of the most elegant instruments in the whole compass of musical practice.

The guitar, or cittern, is generally played with the fingers, like the harp, and was in vogue with us some years back, when improvements were made on it, particularly by the addition of six keys, corresponding with the six wires; these were called boxed guitars, and, by some, piano-forte guitars. The instrument has a broad neck, on which are various frets, made of wires, fixed into the finger-board, at right angles with the wires; these being the guides for the fingers to make the several notes, by pressing between the frets. The bridge is very low, and stands behind a circular sound-hole, covered with an ornamented and perforated plate; the body of the guitar is of an oval form, the sides perpendicular to the belly and back. This instrument is strung peculiarly; the upper open note, G, is of double steel wires, about No. 4; the second, E, is also double, No. 5; the third is of brass, double, and gives C; the fourth is double, of brass, and gives G, an octave below the upper wires; the fifth is E, an octave below the second wires; and the sixth is C, the octave below the third. The two last are single wires, covered with very fine wire, as closely as possible, like the fourth strings of violins. The wires loop at the bottom to little ivory studs, and at the top to small steel studs, moving in grooves, each of them winding up with a watch-key, so as to put them in tune respectively. The Spanish guitar is strung with cat-gut partly; but the lower notes are, like those of the harp, made of floss-silk, covered very closely with fine wire. The Spaniards are supposed to be the inventors of the guitar, who derived its name Guitarra from Cithara, the Latin denomination for almost every instrument of the lute kind. These people are so partial to music, and to that of the guitar in particular, that there are few, even of the labouring class, who do not solace themselves with the practice of it. They use the guitar to serenade their mistresses, and there is scarcely an artificer in any of the cities, or principal towns, who, when his work is over, does not entertain himself with his guitar.

The clarichord of the Germans differs from other keyed instruments by the length of the string, which is attached at one end to a bridge, and at the other to a pin or screw as usual, but the effective length is terminated on one side by the bridge, and, on the other, by a flat wire projecting from the end of the key, which strikes the string, and likewise serves as a temporary bridge as long as the sound continues. The remainder of the string is prevented from sounding by being in contact with a strip of cloth, which stops the vibration as soon as the hammer falls. The instrument is capable of great delicacy, but is deficient in force.

Of the drum species we have an abundant variety. The side, or military drum, is well known; it is of a cylindrical form, hollow, and covered at each end with parchment, that can be stretched or relaxed at pleasure, by means of cords or braces, acted upon by bands of leather. It is monotonous, but habit has so far reconciled us to its uses that we consider it as a musical instrument, though it is not in strictness entitled to that designation, nor is any instrument of this description to be so classed, excepting the kettle-drum, or timbale, which being regularly tuned, the one to the key-note, and the other to its fourth below or fifth above, are satisfactorily and efficiently introduced into full bands, in which their emphasis, their powers, and their thundering roll, frequently prove very acceptable aids, and produce the richest effects. The kettle-drum derives its English name from its form, the bottom being a large semi-spherical kettle of copper, and the head being of vellum, or goat-skin, stretched on a metal hoop, which being lowered or raised by screws at pleasure, so as to vary the internal measurement, can be tuned precisely to any given intonation. They are accounted bass-instruments, on account of their grave sounds. Though our cavalry, for many years, were generally provided with kettle-drums, yet they were not of our own invention; nor were they known in Europe before the Holy Wars, when they were first adopted from the Saracens, or Moors, who were accustomed to carry them, of immense bulk, suspended on either side of camels; the driver beating as the animal moved on.

The tabor is a small drum, so flat, that the two heads are not more than three inches asunder. It is only used as an accompaniment to the pipe, for dances, &c. Both are played by the same performer: while the tones of the *pipe* are regulated by the fingers of the left hand, which stop the holes, the *tabor* is beat by the right. The tabor and pipe are favourite instruments with the common people of most countries in Europe, and are particularly calculated for dancing parties.

The tambourine is a kind of drum with only one head, the other end of the hoop, which is not more than four inches in breadth, being open. It is furnished at the sides with small bells and loose bits of tin. The head, which is of the best parchment, is fixed to an iron rim, and by means of screws fixed to the exterior of the hoop, can be tightened at pleasure. The performer puts the thumb of his left hand through a hole in the hoop, lined with an ivory moveable box, to prevent chafing. In this manner he whirls the tambourine about, and makes the brass jingles or cymbals (as they are called), which are inserted in pairs, through slits in the hoop, strike so as to produce various sounds, either clashing or tremulous, according as he may apply his right hand. It has been denominated a tinkling cymbal.

The triangle is a round steel bar, about the third of an inch thick, made into an equilateral triangle, and beat

beat with a little piece of the same metal; it forms a passable accompaniment in a military band, and in country dances gives life to the music. It appears to be of a very ancient invention, though revived only within these few years.

The organ is an instrument of the highest antiquity, in the structure of which the greatest ingenuity has been displayed. The reader cannot expect to find here a detailed description of so very complex an instrument; but we shall endeavour to afford such a perspicuous and general outline, as may exhibit the principal parts sufficiently for his purpose. The most difficult to make properly, is the wind-chest, which is an extensive, horizontal box, so closely fitted and prepared, as to retain the wind impelled into it by various large bellows, which must be numerous, and capacious, in proportion to the size of the wind-chest. The quantity of wind in it is always known to the organist by means of a tell-tale, or index, attached to the bellows, which rises and falls in proportion to the quantity of air, and apprizes the performer in what degree the wind is exhausted. The top of the wind-chest is bored with several lines of apertures, proportioned to the sizes of the pipes they are to receive, those of the bass-notes being the largest; but all the pipes in each row being different as to their interior construction, and consequently producing very different sounds, each row is called a *stop*, and has a plug appropriate to it, acting upon a slide, which shuts or opens the whole of that row at pleasure; this is called a register. There are as many of such rows of apertures or registers as there are kinds of tones or stops on the organ: some having few, others having numerous stops. The wind is prevented escaping from the wind-chest into the pipes by valves, which are opened only when the performer presses the keys respectively; when, by means of communicating wires, the valves are pressed down, and the wind passes into the pipes. When the key is quitted, the pressure of the wind, aided by a spiral wire spring shuts the valve, and the sound of that pipe instantly ceases. In order to regulate the force of the sound, most church-organs have either two or three rows of keys, whereby a greater or less number of pipes may be filled, and the powers of the instrument be controlled into what is called the small organ, or be let loose so as to become the full organ. The pipes suited to the higher notes are made of mixed metals, chiefly tin and lead; they increase in length and diameter in proportion to the note; until, metal pipes being no further applicable, square ones of wood are substituted in their stead for all the lower notes. The dimensions of all the pipes of an organ are regulated by a scale or diapason, formed for the use of manufacturers in this line, and apportioned to every size of instrument usually made.

The following are the stops usually made in a great organ:—The open diapason, in which all the pipes are open at the top; this is a metallic stop. The stopped diapason, the bass-notes of this, up to the tenor C, are always made of wood, and are stopped at their summits with wooden plugs, by which the tone is very much softened. The principal is the middle stop, and serves, when tuned, as the basis for tuning all the other parts, above and below; it is metallic. The twelfth is metallic also, and derives its name from being a twelfth, or an octave and a half, above the diapason. The fifteenth, so called, because it is two octaves above the diapason. The sesquialtera is composed of various pipes, tuned in the parts of the common chord; the upper part is often called the cornet. The furniture-stop is very shrill, and in some passages has a peculiarly fine effect. The trumpet is a metallic stop, and derives its name from the instrument it so admirably imitates: this peculiar tone is produced by means of what is called a reed, but is in reality a piece of brass, on which the wind acts forcibly, giving a roughness to the sound, which is further changed by all the pipes of this stop having bell-mouths like trumpets. The clarion is a reed-stop also, but an octave higher than the trumpet; it is only suited to a full chorus. The tierce is only employed in the full organ, it being very shrill, and a third above the fifteenth. The octave above the twelfth is too shrill to be used but in the full organ. The cornet is a treble stop. The dulcimer takes its name from the sweetness of its tones. The flute is named from the instrument it imitates, as are the bassoon, vox-humana, hautboy, and cremona, or krum-horn stops. The proper adaptation of the several stops in the performance of sacred music, and in accompanying a choir, requires both judgment and experience. The fingering of an organ is precisely the same as that of the piano-forte, so far as relates to the situation of the keys, &c.; but on account of the great number of holding-notes in organ-music, the fingers are more kept down, whence it is considered highly injurious to piano-forte performers to practise the organ, they being subject to lose that lightness, and that delicacy of touch, required for the former instrument.

Organs are likewise made without keys, but with barrels, on which are a great number of pins and staples of flat brass wire, and of different lengths. The barrel being turned by means of a crank, or winch, the wires that communicate with the valves in the wind-chest are acted upon by the pins and staples; which hold down the valves for a longer or a shorter time, according to the duration of the notes they respectively govern. On these barrels, which are made to shift at pleasure, from ten to fifteen tunes are usually made. The winch not only turns the barrel, but also works a pair of bellows, by which the wind-chest is supplied. This instrument is called the hand, or barrel-organ, and is very common in London streets.

Of all musical instruments the organ is the most proper for the sacred purpose to which it has been generally applied, in almost all countries wherever it has been introduced. Its structure is lofty, elegant and majestic, and its solemnity, grandeur and rich volume of tone, have obtained for it an acknowledged pre-eminence over every other instrument. The invention of the organ is certainly of very ancient date, some writers carry

carry it as far back as five or six centuries before the birth of Christ. It has been a subject of debate at what time the use of organs was first introduced into the Christian church. Some writers say they were first applied to sacred purposes in the year 600, by Pope Vitalian; others contend they were not known in that way till the ninth century; but it is asserted by Thomas Aquinas, that in his time, viz. the middle of the thirteenth century, the church did not use musical instruments. There are, however, other authorities which positively declare that organs became common in Italy and other parts of the Continent, as well as in England, in the tenth century. We may observe, that though of such long standing, yet Christians are by no means unanimous as to the lawfulness of music in divine service. The discussion has sometimes been carried on with great zeal, not to say bitterness, by different sects and denominations. The arguments on both sides of the question are briefly, but very candidly, stated in an excellent little work just now published by Johnson and Co., entitled, "A new Directory for Nonconformist Churches."

Before we quit the organ we may just observe, and the observation will hold with respect to the manufacturers of other musical instruments, that the organ-builder, whose profession is to construct and to tune and repair organs of every description, should possess a nice, accurate, and highly cultivated ear, and a sound judgment in the vibratory qualities of wood and metal. The organ-builder should be acquainted with the science of pneumatics and practical mechanics, and he should be so far informed in the simple elements of musical composition as in some degree to be capable of trying the different stops and combinations of his own instruments, and of deciding for himself on the effects in performance.

The Mouth Organ, or Pan's Pipes, are well known, being so often played as an accompaniment to organs, &c. in the streets; they consist of a range of pipes bound together side by side, gradually lessening with respect to each other in length and diameter. The longest is about six inches, and the shortest about two inches in length. They are of various sizes and extent, some being nearly three octaves; however, a few have a chromatic scale, at least for the adjunct keys: *i. e.* those of the fourth and fifth. The tones of the mouth organ are very agreeable, but are best heard at a little distance; when, either as an aid to the organ, or in performing pieces arranged for several mouth-organs, as is very common, they have a very pleasing effect; when played in a room, the notes are piercing, and the sibilations are apt to be very offensive.

The Eolian Harp may be best included in this class, though it will not answer in every particular. It consists of a long box, in which four or more strings are stretched its whole length, and tuned to the component parts of any common chord, such as C, E, G, C, E, G, &c.: opposite the line of the strings, which stand over a slanting sounding-board, are two slits, one on each side, running parallel with the entire strings. This instrument being placed opposite to a window, opened only an inch or two, the air will rush through the slits, and vibrating upon the strings, in its passage through the box, will cause a kind of tremulous murmuring repetition of the various notes. The Eolian harp is by no means a disagreeable companion, when perfectly in tune. Some idea of its notes may be formed by stretching a thin violin string over the narrow slit between the upper and under compartments of a sash window; these being generally rather open, allow the wind to pass, and will cause the string to keep perpetually humming that note it yields when plectrated or touched by a bow. It changes from one note to another, as the force of the wind varies, and as it acts on different parts of the string.

The Trumpet, with all its tribe, now comes under consideration. This most audible instrument is made of metal; those of silver are by far the softest in tone; but brass is in general used. The modern trumpet is very short and portable compared with the old form of the instrument: its tone or pitch is varied by means of additional pieces called crooks, by which it may be made to accord with any given key-note. It has a mouth-piece, which is about an inch in diameter, concaved for the lips to act within, and closing into a very narrow tube, through which the wind passes with considerable force into the neck of the instrument. The trumpet is a treble instrument; but, excepting from C in the middle of the stave to its octave above, can only perform the three under notes G, E, C, and G in the bass; in the above octave it can only deviate from the key C, by a sharp fourth leading into the key of G. In saying this we speak of the instrument unaided by the hand; for by various modes of fingering within the bell, or mouth, the trumpet can be made to yield a great variety of semi-tones. Trumpets with slides, which suddenly lower or raise the pitch one or two notes, are capable of great execution, and may be made to yield every note and semi-tone within their whole compass, so as to go through all the intricate passages of solo-concertos; but to perform in such style, and, indeed, to manage the slides with tolerable accuracy, requires a faithful hand and the greatest promptness. We have various sizes of trumpets, some intended for concerts, and of course furnished with crooks; others are in use with our cavalry, made short and compact, and invariably pitched to one key; it is not unpleasant, though rather uncommon, to hear the trumpets of a cavalry corps sounding their several calls in parts: though the harmony is not varied, there is yet something in it that reconciles one to its narrow limits, and indeed to the imperfectness of many reputed concords; few of which can be sounded correctly on trumpets.

The next in this class is the French Horn; of which we have various sizes and descriptions. It consists of a long tube twisted into several circular folds, gradually increasing in diameter from the end at which it is blown to

to that at which the wind issues. Those intended for concerts, have, like the trumpet, various crooks and a slide whereby they may be brought to accord with the most scrupulous exactness. The horn always has its music written in the key of C, and acquires any other key at pleasure, by the addition of such crooks as may bring it to the proper pitch: the more crooks are affixed, the deeper will be the intonation. There is a very strong affinity between the horn and the trumpet, in regard to their capability of producing particular notes; what has already been said of the latter, in that respect, applies equally to the former. The finest notes of this instrument lie near the middle of the treble stave, or at farthest between G and C; though its low notes, when properly sounded, are very fine and mellow. The natural fourth is said to be seldom in tune, and therefore avoided by composers who are acquainted with the constitution of the instrument.

The Serpent, so called from its form, seems to be the link that connects the horn with the flute species; its mouth-piece is indeed very similar to that of the trumpet, but it is made of ivory. This is the deepest bass instrument of all that have finger-holes, and which, consequently have a chromatic compass. But the serpent has some of its lowest notes entirely dependant on the lip-play of the performer. This instrument descends two notes lower than the bassoon, and reaches up to F, on the clef line of the bass, with perfect facility and correctness of intonation. Some performers can by great practice advance several notes higher. The serpent is made of very thin wood, covered with buckram and leather, so as to become very firm: hence its tone is by no means smooth, the materials vibrating so very forcibly as to roughen the sounds, especially among the low notes. It has three distinct parts, viz. a mouth-piece, neck, and tail; and six finger holes, each lined with ivory, ebony, &c., requiring a very firm hand to stop them well. This instrument forms an exact reinforcement to the basses of a military band, to which it is chiefly appropriated.

The Flute is, by many, supposed to be of English invention, but it appears to resemble the old calamus, or shepherd's pipe, more than any other of this species. the sound is generated by blowing through a slit into the bore, the superfluous wind passing out at a vent made on the top, close to the upper end; there are seven finger-holes above, and one for each thumb below; some have only one thumb-hole, others two small ones, like the G on a hautboy for the purpose of making a semi-tone. All the flageolet tribe, which are of various sorts and sizes, belong to this species. The common flute is also made of various dimensions, thence assuming various designations of second, third, and fourth, &c., according as it diminishes in size, and becomes shriller in tone. The common flute yields a very soft agreeable sound, and is very appropriate to little artless airs; but, having very little power, is by no means adapted to join in a band. The flageolet is, however, introduced, on many occasions, into dramatic orchestras, and finds a place in some bands; its very piercing notes may be at all times distinguished. The several kinds of flutes are distinguished according to the number of keys, to their purposes, and to their sizes; they are generally called seconds, thirds, &c., as they recede from the standard, diminishing gradually according to the above terms.

The Bagpipe is of two sorts; viz. the Scots and the Irish: the former is filled by means of a wind-bag, carried under the arm and worked like a pair of bellows; the other plays with a reed like the hautboy. These two species have, within these few years, been blended, under the designation of union-pipes; both are fingered much the same as a flute, and have a drone or open tube through which the wind passes, causing a deep humming tone. It is thought that the Norwegians and Danes first introduced the bag-pipe into the Hebrides, which islands they long possessed.

We may further observe, that in mixed wind instruments, the vibrations of solid bodies are made to co-operate with vibrations of a given portion of air. Thus in the trumpet, and in horns of the several kinds, the force of inflation, and perhaps the degree of tension of the lips, determines the number of parts into which the tube is divided. In the serpent, the lips co-operate with a tube, of which the effective length may be varied by opening or shutting holes, and the instrument which has been called an organized trumpet appears to act in a similar manner. The trombone has a tube which slides in and out at pleasure, and changes the actual length of the instrument. The hautboy and clarionet have mouthpieces of different forms, made of reeds or canes, and the reed-pipes of an organ are furnished with an elastic plate of metal which vibrates in unison with the column of air they contain.

The class of collision seems to appertain exclusively to those instruments which are provided with strings or wires, and are played upon by means of a piece of curved wood, subtending a quantity of horse-hairs, regularly disposed in a flat and parallel manner: these we call bows; they are of various sizes, according to the instruments to which they are respectively applied; namely, the double bass, the violincello, the tenor, the violin, and the kit.

The violin may be considered as the chief of this tribe: it will be unnecessary to describe its form, &c., the instrument being so universally known: its scale extends from G above the bass clef up to double D in alt; beyond which, though notes may be made, the tone becomes rather offensively shrill, and, generally speaking, borders on a kind of whistling scream. The pre-eminent expression, and the wonderful execution which may be effected with the violin, added to the great compass (it being full three octaves and a half), justly occasion this incomparable instrument to take the lead in concerts and orchestras; and, in general, in all musical meetings. It is to be lamented, however, that we cannot boast of so complete an intimacy with the

the construction of the violin and of all its class, as Italy and some other parts of the Continent.

All the violin class have four strings, fastened at one end to a small piece of ebony, called the tail-piece; and, after passing over a raised bridge, made of seasoned beech-wood (particularly the back of old instruments), and over a little ridge called the nut, are fastened respectively to four pegs made of very hard tough wood, by the turning of which they are put in tune; all the strings give fifths to their neighbours throughout; thus the first string is E, the second is A, the third is D, and the fourth, which is a covered one, is G. The tenors and basses have no E string, but a C one added below the G. The notes are made by compressing, i. e. by what is called stopping the strings on a rounded slip of ebony, called the finger-board, which proceeds from the nut full four-fifths of the distance between that and the bridge; the latter being always placed on the belly, or sounding-board, exactly between the centres of two sound-holes, which are in the form of an S. The belly is supported by a small piece of rounded deal called the sounding-port, without which the tones would be imperfect and harsh.

Mr. J. C. Becker, of London, obtained some years since, His Majesty's letters patent for improvements in musical instruments. His invention, it appears, consisted chiefly in some improvements in the harp and piano-forte. With respect to the harp, he produces the sharps, flats, quarter-notes, or any intermediate variation deviating from the natural notes, by causing the wrest-pins, that is, the pins by which the strings are extended and tuned, to move partly round centres and thereby increase or decrease the tension of the strings more or less, as may be required to answer the desired change of the notes. For this purpose the wrest pins are connected with the pedals by a particular apparatus. In the specification there are figures representing a wrest-pin passing through a socket, with a lever, on which slides a quadrant; and on this quadrant are fixed links that are kept stationary by a regulating screw. The links communicate with the pedals by the interposition of a crank. On the crank is also a regulating screw to adjust the whole to the motion of pedals. Now if one of the pedals is pressed down, all its appertaining quadrants with the wrest-pins must follow, and of course the tension of the appending strings will be increased accordingly; and as soon as the pedal is left at liberty, the strings will, by their re-action, resume their former degree of tension, and the pedal its former station; hence a variety of changes may be effected on each string throughout the instrument by the motion of the pedals. If in case new strings are put on, perhaps differing in size and quality, any irregularity should take place, this is to be corrected by the regulating screw. To stop the pedals at four different stations, answering to the natural note, to one-quarter, to one-half, and to three-quarter notes, a rack is applied which preserves the pedal in each situation in a perpendicular line, and thereby prevents them coming too close to one another. To ease the motion of the pedals, having each of them six or seven strings to act upon, the patentee applies a spring to each pedal, to counteract the tension of the strings, and thus to render the motion of the pedals as easy as necessary.

In piano-fortes, or other stringed instruments played with keys, he uses one or more wheels, to cause the strings to vibrate. These wheels are placed under or above the strings, and put into motion with a pedal or pedals, or any other mechanical power, and the strings are by the touch of the keys inclined to the wheels. In the manner of extending and inclining the strings consists the principle of the invention. The principle will admit of a variety of forms and applications. If therefore the string be any-wise extended on any thing moveable, having its fulchrum any where within the extent of the string, the patentee claims that as the principle of his invention.—He further adds, that by his simple contrivances the pedal harp is rendered the most perfect of any musical instrument whatever; because on it the skilful musician can raise and depress each note at pleasure, and thereby modulate and introduce graces beyond the limits of composition.

NAIL-MAKING.

Nails, in building, &c., are small spikes of iron, brass, &c., which being driven into wood serve to bind several pieces together, or to fasten something upon them. The several sorts of nails are very numerous: as, 1. Back and bottom nails, which are made with flat shanks to hold fast and not open the wood. 2. Clamp-nails, for fastening the clamps in buildings, &c. 3. Clasp-nails, whose heads clasping and sticking into the wood render the work smooth, so as to admit a plane over it. 4. Clench-nails, used by boat and barge

barge builders, and proper for any boarded buildings that are to be taken down, because they will drive without splitting the wood, and draw without breaking; of these there are many sorts. 5. Clout-nails, used for nailing on clouts to axle-trees. 6. Deck-nails, for fastening of decks in ships, doubling of shipping, and floors laid with planks. 7. Dog-nails, for fastening hinges on doors, &c. 8. Flat-points, much used in shipping, and are proper where there is occasion to draw and hold fast, and no conveniency of clenching. 9. Jobent-nails, for nailing thin plates of iron to wood, as small hinges on cupboard-doors, &c. 10. Lead-nails, for nailing lead, leather, and canvass to hard wood. 11. Port-nails, for nailing hinges to the ports of ships. 12. Pound-nails, which are four-square, and are much used in Essex, Norfolk, and Suffolk, and scarcely any where else, except for paling. 13. Ribbing-nails, principally used in ship-building, for fastening the ribs of ships in their places. 14. Rose-nails, which are drawn four-square in the shank, and commonly in a round tool, as all common two-penny nails are; in some countries all the larger sort of nails are made of this shape. 15. Rother-nails, which have a full head, and are chiefly used in fastening rother-irons to ships. 16. Round-head nails, for fastening on hinges, or for any other use where a neat head is required; these are of several sorts. 17. Scupper-nails, which have a broad head, and are used for fastening leather and canvass to wood. 18. Sharp-nails, these have sharp points and flat shanks, and are much used, especially in the West Indies, for nailing soft wood. 19. Sheathing-nails, for fastening sheathing-boards to ships. 20. Square-nails, which are used for hard wood, and nailing up wall-fruit. 21. Tacks, the smallest of which serve to fasten paper to wood; the middling for wool-cards, &c., and the larger for upholsterers and pumps. Nails are said to be toughened when too brittle, by heating them in a fire-shovel, and putting some tallow or grease among them.

Such are some of the various descriptions of nails employed by mechanics in the different arts of life, and as new arts and new inventions arise from human ingenuity, other kinds of nails will be formed, adapted to the several purposes for which there is a demand. Formerly the nail-maker's process was very tedious, every nail being made by the hand, and each begun and finished by the same individual; it was afterwards discovered in this manufacture, as in many others, that by a division of labour, and by assigning to different persons the *pointing*, the *heading*, &c., a greater quantity of work was done by the same number of hands; of course the processes were much simplified, and expedited, and the article could be sold on much lower terms.

Within the last five and twenty years divers ingenious mechanics have not only improved the methods of manufacturing nails, but have thought it worth their while to secure to themselves the exclusive right of their inventions by obtaining the king's letters patent: of some of these we shall proceed to give an account.

In the year 1790, Mr. Thomas Clifford, of the city of Bristol, obtained two patents for the manufacture of nails of every kind. The principle on which his first invention is founded, was that of making the nails in a die; that is, by having a die or the impression of the nails to be cut into one or more pieces of iron, steel, or other metal, and the iron of which the nails are to be formed, is drawn or rolled into the proper form or thickness, and, by a force adapted to the purpose, pressed into a cavity or die, so as to form the nails, either complete or so nearly complete as that they can be finished with a very little labour. This operation may be done in several ways, but the one particularly recommended by Mr. Clifford, is by rollers of iron or steel, and worked either by water, steam, wind, horses, &c.

The two rollers are to be made of iron and cased with steel, each of the same diameter, and the diameter proportioned to the length and size of the nail intended to be made. Each roller should have one or more cog-wheels, the cogs of one roller to work into those of the other, so that the rollers may both perform the same exact revolution. One half the impress of the nail is to be cut with one roller, the other half in the other, so that the two impressions form a cavity, or die, of the exact form of the nail, extending the lengthways of the nail on the circumference of the rollers; and as many impressions of the same kind may be cut in the rollers, one at the end of the other, as will complete their circumference, and continue the cavity all round the rollers: the point of one nail joining the head of the next, or the two points and two heads joining each other. The rollers must in this, as in other cases, be made to work very true, and close to each other.

The mode of operation is this; a rod of metal, iron for instance, rolled or drawn to a convenient size is to be heated, and, while hot, the end of it is put between the rollers, into the cavity or die which forms the impression of the nail. The rollers being now put in motion, will draw the iron through, pressed into the cavity or die which forms the impression of the nail, the one joined to the other, which must be afterwards separated by means of instruments acting as nippers, shears, chisels, &c. The rollers being made to work very close to each other, where the edge of the nail is formed, will prevent much of the metal from being pressed out on each side of the nail, and what is pressed out may be cut off by instruments adapted to the purpose. Several pairs of rollers may be made to work together, and each pair may have several rows of dies cut on them, so as to form the impression for several strings of nails; and a rod of iron, being put into each of them, will roll out as many strings of nails with one revolution of the rollers. A pair of rollers may also have the greater part of their surface cut with dies, and a flat bar, or piece of iron, be made to pass between the rollers, so as to form sheet nails; the whole of them

them connected to one another by thin plates of iron, of which they are composed, and this would require each nail to be cut out or separated from the sheet by proper instruments.

Mr. Clifford's second invention consists, 1. In drawing the iron, or other metal, into a tapering or wedge-like form, according to the length and thickness of the different sizes of nails to be made. 2. The nails are to be cut out of those wedge-like or tapering plates, by means of a punch, the face of which is made according to the size, taper, and form, of the nail to be cut out; as also having a hollow bolster, the hollow or aperture of which must also be made of the size and form of the nail, and consequently to fit and receive the punch above-mentioned. The punch thus fitted to the bed, and sliding in the frame to keep it steady, will, by a blow, or by pressure, cut or force a part of the taper plate into and through an aperture of the bed fitting to it, and by which the nail is formed. This operation is by the manufacturers of buckles, buttons, &c., generally called cutting-out. 3. To form the heads of horse-nails, called rose-heads, and others of nearly a similar kind, after the operations of drawing and cutting out, the nail is to be put into a heading-tool, which is also called a bed, which bed receives the nail, excepting a small portion, at the thick end of which the head is formed, by a punch or die. This die, by a blow, or pressure, forms the head as required; and when the nails are made of hard iron, after they are cut, in the way described, the thick end is made hot before they are put into the bed or heading-tool. 4. Another method adopted in the manufacture of nails, is by cutting them out of or from plates of equal thickness, and afterwards to point them, either by a hammer or other pressure. 5. In making nails that are of a triangular form, the plate or strip of iron is pressed or stamped into a die, having impressions cut to the form of such nails, after which they are cut out by a punch.

About the same period in which the foregoing patents were obtained, Mr. William Finch, of Woombourne, in Staffordshire, invented another method of making nails and spikes by machinery, to be worked by steam, &c., by which all manual labour was to be saved. In his specification he describes his power as consisting of one main shaft, caused to revolve in either a horizontal or perpendicular direction by means of a water-wheel, or a steam-engine. Such main shaft will put in motion, by means of cogs and pinion-wheels, other counter-shafts or barrels, on which are fixed arms, &c., and on these are hammers that are worked in either a lift, or tilt manner. He also makes three divisions of hands in the manufacturing of headed-nails, namely, one man, woman, or child, to carry the heated rod to the man, woman, or child, stationed before the hammer, which person, by mere activity, will with one hand not only form the largest size nail, but a far greater number in the same given time: when the third person, will, with the same kind of hammer, head and finish a number of the said shanks together, leaving them truer made, and better for use, than the present mode. Also, by a division of hands, will make such nails as require no tool or frame to be headed in; namely, the one to carry the iron from the fire, and the other stationed before the hammer to finish them. In enumerating the advantages and savings of this method above the others then in use, Mr. Finch says, that by heating many rods in one fire, there will be a saving of coal:—by the more speedy motion of machine-hammers, several nails will be made at once heating the rod, whereas, by the old method, only one is made:—again, the motion being regular, independently of strength, a child will be able to make the largest nail or spike. A farther benefit, it is said, will arise to the manufacturer by this mode, viz. that he will have his business done at one place, or under one roof, whereas, by the old method, the workmen sometimes live many miles asunder, and cannot be overlooked. Likewise, by this method, the limbs of those employed in the manufactory will be preserved to the end of life, but, in the old method, it frequently happened that nail-makers were lamed in a few years, and became burdensome to the parish.

Another invention of this kind is that for which a patent was obtained in 1808, by Messrs. Willmore and Tonk, and which may be thus described:—

"They take a nail-rod, of a size suitable to the size of the nail intended to be manufactured, and applying it to a common screw-press, mounted with proper cutters, cut off from the end of the rod two pieces at once, obliquely across the rod in one place, and directly across it in another. Two studs or stops are set up, which are attached to the press, and are moveable in the direction of the rod, for the purpose of ascertaining the length of the nail; and both studs are adjustable in the cross direction of the rod, so that the obliquity of the cut, according to the kind of nail to be made, is thereby determined, as well as the length of the nail. This is called the first operation.

"The second operation is to anneal the pieces so cut off, if the iron should not be sufficiently malleable, which is done in the usual and well-known manner. The third operation is that of heading, which for clasp-head nails, consists of two parts, one for gathering, and the other for forming the head of the nail. The first part of this operation is performed by putting a piece cut off the rod of iron, as before described, into a pair of clams, leaving as much of the thick end projecting above the clams as is sufficient to form the head. These clams have steel bits let into them with sharp edges, which press only against the two opposite sides of the piece, and which have the effect of two chisels when the punch of the press is brought down upon the piece with considerable force, and raise or gather up iron on each side towards forming the head. The second part of this operation is to put the piece thus prepared into another pair of clams, having bits formed to correspond to the under side of the head; and the punch, having the impression of the upper side of

of the head engraved or sunk into it, is brought to press strongly upon the head in the clams, and thereby the clasp-head is properly formed.

"For nails intended to have rose-heads, or any other kind of heads, except clasp-heads, the first part of this operation is not absolutely necessary, but the bits, which for clasp-nails must have sharp edges, must for the other kind of nails have blunt edges, to prevent the under-cutting. For the second part of this operation, the piece is put either into a pair of clams, or into the tool commonly called a bore, and then pressed with punches, properly engraved or sunk, according to the kind of head wanted. By the first operation, the piece cut off the rod of iron is formed something like a mortise-chisel; the fourth operation is to point it, which is done by putting the piece into a bed of steel, in which is cut a nick or groove, having parallel sides, but the bottom rising towards the end where the point of the nail is to be formed. The punch is shewn in the specification, and the end which presses upon the point of the nail is made to project farther than the other part, so as to meet the corresponding part of the bed when the punch is brought upon the nail. The groove, or nick, in the bed should be just wide enough to receive the piece easily, but prevent it from twisting when the impression is made. The piece is put twice into the nick; once with the chisel, the end lying horizontal, and next turned a quarter round, to press the chisel edge into a pointed form. If the nails, by the strong pressure which is necessary in this operation, should become too hard to clench, they anneal them in the ordinary way, which may be called the fifth operation. The third, fourth, and fifth operations above described are applied to nails, or pieces cut off from sheet or rolled iron in the ordinary way; but as they, in consequence of the fifth operation, which is necessary to give them the quality of clenching, are apt to be too soft to drive well, a sixth operation is applied, viz. quenching them, when red hot, in water or other proper fluid, which gives them stiffness enough to drive without destroying the quality of clenching. Figures attached to the specification show, 1. A pair of clams, with bits or dies let into them, which can be renewed from time to time with more ease, and at less expense, than by the usual method. These bits are proper for the first part of the third operation. 2. A pair of bits, or dies, proper for making either rose-heads or flat heads. 3. A pair of bits, or dies, proper for the second part of the third operation for clasp-head nails. 4. A view of the common screw-press, in which is shown the side-pin, or screw, by which the clams are firmly pressed together at the time the punch is pressed down upon the nail. This pin, or screw, is generally worked by the foot, by means of the lever connected with a treadle, while the hand applies its force to the handle of the fly; but to the head of the main screw is fixed a portion of a pulley (or a whole one), to which is attached a rope, chain, belt, or other connecting pliable material, which flying round the edge of another pulley fixed to the frame of the press, and standing vertically descends, and is attached to the moveable end of the treadle; and on this treadle is placed a weight, heavy enough to press the clams together with sufficient force. By means of the latter described machinery, which is the only part claimed by the patentees as their invention, the operation of pressing is performed by the action of the hand only, and is found very convenient."

We may mention, in connexion with this subject, a new method, or improvement in the manufacture of bagging for packing of nails, adopted by Mr. Benjamin Haden, of Sedgley, in Staffordshire. He takes for his warp, hurds or tow, prepared in the usual way, such as are in common use in the manufacture of nail-bagging, but for his wefts or woofs he takes old ropes, or junk, of any dimensions; and after untwisting or dividing the threads or filaments thereof, he winds it into bobbins or quills, and then they become fit for the shuttle; and he weaves them with the common warp in the common way. The materials just mentioned are said to be peculiarly adapted to give strength and durability to the article, and are therefore perfectly fit for the bagging of nails. The yarn, of which ropes are generally made, particularly king's ropes, is spun from the choicest hemp, and strongly impregnated with tar. The threads taken from the middle of such ropes, not having been exposed to the weather, or to friction, are as sound and as strong as when originally used. The tarry matter with which these threads are impregnated, renders them peculiarly advantageous in the manufacture of sacks that require great strength, and substance, the weft being composed of these threads, finely spun, which are good and strong, tenacious, and not liable to rent or perish with the wet, nor to burst in carriage, to the great loss of those concerned.

NEEDLE-MAKING.

NEEDLE, a very common little instrument, or utensil, made of steel, pointed at one end and pierced at the other, used in sewing, embroidery, tapestry, &c. Needles make a very considerable article in commerce, though there is scarce any commodity cheaper, the consumption of them being almost incredible. The sizes of common sewing needles are from No. 1, the largest, to No. 25, the smallest. Besides sewing-needles there are, under the denomination of needle, the netting and the knitting-needle: the glovers' needle, with a triangular point; the tambour needle, which is made like a hook, and fixed in a handle, the hook being thrust through the cloth, the thread is caught under the hook, and the needle is drawn back taking the thread with it.

In the manufacture of needles, German and Hungarian steel is of most repute. In the making of them, the first thing is to pass the steel through a coal fire, and under a hammer, to bring it out of its square figure into a cylindrical one. This done, it is drawn through a large hole of a wire-drawing iron, and returned into the fire, and drawn through a second hole of the iron smaller than the first; and thus successively from hole to hole, till it has acquired the degree of fineness required for that species of needles; observing every time it is to be drawn, that it be greased over with lard, to render it more manageable. The steel thus reduced to a fine wire, is cut in pieces of the length of the needles intended. These pieces are flattened at one end on the anvil, in order to form the head and eye; they are then put into the fire to soften them farther, and thence taken out and pierced at each extreme of the flat part on the anvil, by force of a puncheon of well-tempered steel, and laid on a leaden block to bring out, with another puncheon, the little piece of steel remaining in the eye. The corners are then filed off the square of the heads, and a little cavity filed on each side of the flat of the head; this done, the point is formed with a file, and the whole filed over: they are then laid to heat red-hot on a long narrow iron, crooked at one end, in a charcoal fire; and when taken out thence, are thrown into a bason of cold water to harden. On this operation a good deal depends; too much heat burns them, and too little leaves them soft; the medium is learned by experience. When they are thus hardened, they are laid in an iron shovel, on a fire more or less brisk in proportion to the thickness of the needles; taking care to move them from time to time. This serves to temper them; and to take off their brittleness; great care here too must be taken of the degree of heat. They are then straightened one after another with the hammer, the coldness of the water used in hardening them having twisted the greatest part of them.

The next process is the polishing them. To do this, they take 12 or 15,000 needles, and range them in little heaps against each other on a piece of new buckram sprinkled with emery-dust. The needles thus disposed, emery-dust is thrown over them, which is again sprinkled with oil of olives; at last, the whole is made up into a roll, well bound at both ends. This roll is then laid on a polishing table, and over it a thick plank loaded with stones, which two men work backwards and forwards a day and a half, or two days, successively; by which means the roll thus continually agitated by the weight and motion of the plank over it, the needles withinside being rubbed against each other with oil and emery, are insensibly polished. After polishing they are taken out, and the filth washed off them with hot water and soap: they are then wiped in hot bran, a little moistened, placed with the needles in a round box, suspended in the air by a cord, which is kept stirring till the bran and needles be dry. The needles thus wiped in two or three different brans, are taken out and put in wooden vessels, to have the good separated from those whose points or eyes have been broken either in polishing or wiping; the points are then all turned the same way, and smoothed with an emery stone turned with a wheel. This operation finishes them, and there remains nothing but to make them into packets of from twenty-five to one hundred each.

Such is the ancient method of the manufacture of needles; we shall now give a rather more detailed description as the business is now generally carried on. The wire when drawn to a proper size, which is ascertained by gages, is made up into coils for package: these coils of wire are heated to a dull red-heat in a furnace, and suffered to cool gradually, to soften and anneal it, with a view of facilitating the working of the steel; this commences by cutting the wire into lengths, which is done by a pair of shears. The workman being seated before a bench, takes, perhaps, a hundred pieces of wire for fine needles, and introduces their ends between the blades, which he opens with his right hand, and pressing the ends of the wire against a gage, which renders them all of one length, he cuts them off, and they drop down into a tin pan placed on a small shelf in front of the bench; the ends of the wire are now pressed against the gage, and cut off again. In this way the wires are cut into the lengths of the required needles. The second operation is flatting the end for the

the eye of the needle, which is done by a workman taking three or four pieces of the wire between his finger and thumb, placing them on a small anvil, and striking one blow upon each, expands the end sufficiently to receive the point of the punch which pierces the eye. This the same person does before he lays them down, with a small instrument, fixed on the same block as that to which the anvil is fixed. The end of the needle is placed in a small notch in the bed of the instrument, and is put exactly beneath the punch, and a slight stroke of the hammer punches the eye, and at the same time forms the semi-circular groove near the eye of the needle, to bury the thread. The notch which receives the needle is made in a piece of steel which fits into a dove-tail notch in the bed of the instrument, so that it can be changed for a larger or smaller, correspondent to the size of the needles to be pierced. The workman holds the needles in the same manner as he did for flatting; and placing them one by one, successively in the notch in the bed-piece, pierces them by striking a single blow of his hammer on the end of a slider; the slider is immediately returned by a spring. He now places the next needle under the punch, and when they are all pierced in this manner, he rolls them over by moving his thumb, so as to turn them all half round, and bring them upwards the opposite side to that which was pierced; this being done, he repeats the punching on the other side with a view to finish, and clear the eye, and to form the groove which there is in all needles. They are now rounded at the eye-end to take off the roughness, which is done in an instant by applying them to a grindstone.

The next process is hardening and tempering: the first is done by placing a great number together upon a piece of iron, bent up at the ends and sides that they may not roll off, and introducing them into a small furnace: when they become of a red heat they are taken out, and suddenly plunged into a vessel of cold water; this renders them very hard. Some manufacturers make use of oil, or tallow, and other ingredients instead of water, which substances are supposed to improve the process. The needles thus hardened are returned to the furnace with the oil upon them, and remain there till the oil inflames, when they are withdrawn and again cooled in cold water. This second process tempers them: at first they were quite hard, and so brittle as to break with the slightest touch: the tempering takes off the brittleness, but leaves them hard enough to take a good point. When they are hardened in water, according to the old method, the heat for tempering them can only be guessed at, or estimated by experience, but the flaming of the oil is a much more certain method. The needles are now examined, and many of them will be found crooked by hardening, which are discovered by rolling them over as they lay in rows on a board, and such are selected and made straight by a blow in the notch in the anvil. Being thus straightened they require to be pointed, which is done by a large grindstone turned by a mill, either of water or steam. In this operation the workman, sitting astride before the stone on a block shaped like a saddle, takes up 20 or 30 needles, laid side by side across a small wooden ruler, covered with soft leather; another similar ruler being laid over the needles to confine them. The workman holds the rulers in his hands, and thus presenting the ends of the needles to the grindstone points them with great dexterity. After pointing, they are to be polished in the manner already described. The points are next finished and rendered perfectly sharp, by grinding them upon a wooden wheel covered with emery, being held in the same manner as for the first grinding. They are then cleaned and packed up in certain numbers according to their sizes. A great number of the small packets are made into larger parcels, wrapped in several thicknesses of paper and coverings of bladder and packing-cloth, in which state they are sent to market.

Surgeons' needles are generally made crooked, and their points triangular; however, they are of different forms and sizes, and bear different names, according to the purposes they are used for. The largest are needles for amputation; the next, needles for wounds; the finest, needles for sutures. They have others, very short and flat, for tendons; others, still shorter, and the eye placed in the middle, for tying together of vessels, &c. Needles for couching cataracts are of various kinds; all of which have a small, broad, and sharp point or tongue, and some with a sulcus at the point. Surgeons have sometimes used two needles in this operation; one with a sharp point for perforating the coats of the eye, and another with a more obtuse point for depressing or couching the opaque crystalline lens; but care should be taken in the use of any of these, that they be first well polished with cloth or leather, before they are applied to the eye.

Mr. Warner observes, that the blade of the couching needle should be at least a third part larger than those generally used upon this occasion, as great advantages will be found in the depressing of the cataract, by the increased breadth of the blade of that instrument. The handle, also, if made somewhat shorter than usual, will enable the operator to perform with greater steadiness, than he can do with a larger handled instrument. It is to be observed, that needles of silver pierce more easily in stitching arteries after an amputation, than those made of steel.

We shall close this short article with an account of a patent invention for the manufacture of needles of all sorts by Mr. William Bell of Walsal, which we shall give in his own words.

"The method by which I make needles, bodkins, fish-hooks, knitting-pins, netting-needles, and sail-needles, is by casting them with steel or common fusible iron, called pig or cast-iron, into moulds or flasks made with fine sand. Or, otherwise, I make stocks or moulds of iron or steel, or any other composition capable of being made into moulds, on which stocks or moulds I sink, engrave, or stamp, impressions of

of the said articles. Into these I pour my melted iron or steel (I prefer for my purpose sand casting), and prepare my iron or steel as follows: I melt it in a pot or crucible, in small quantities about the weight of twelve pounds (and upwards to twenty pounds), the more conveniently to divest it of its heterogeneous particles, and to purify it from its earthy or sulphureous qualities. When the iron has attained a proper heat, I take charcoal-dust mixed with lime or common salt, which I throw into the pot of melted iron; and, by frequently stirring it with an iron rod, I bring to the surface of the iron a scoria which I frequently skim off, and thus bring my iron into a refined state. I then pour it into the mould before described. The articles being thus formed are capable of being softened, hardened, or tempered in the usual way by which needles, bodkins, fish-hooks, knitting-pins, netting-needles and sail-needles have heretofore been manufactured; therefore the principal merit of my invention is in casting them instead of making them in the usual way."

HOUSE-PAINTING.

PAINTING, as applied to buildings, comprises in the first place the colouring over all the several kinds of wood, iron-work, &c., employed therein with mineral colours, rendered fluid by saturation with oils, oil of turpentine, &c. A pigment so prepared is spread over them with a brush, and by the repetition of several coats, they together operate to their protection, and at the same time give a variety and neatness to the general appearance of a house. This kind of painting will be divided in this section under its several heads, as it is practised in London, and will embrace the working in common colours, also graining of its several kinds, ornamental painting, inscription writing, &c. &c. All the prismatic colours are occasionally called into use by the painter, and he varies these to suit the taste of his employer into almost every gradation of tint. But the ground-work of all house-painting is formed by a paint prepared from lead, known in the arts as ceruse, or white-lead. This is manufactured for use at places called the White-lead Works, and is performed in the following manner, viz. by rolling leaden plates spirally up, so as to leave the space of about an inch between each coil, and afterwards placing them vertically in earthen pots, at the bottom of which is some good vinegar. The pots are then to be covered, and exposed for a length of time to a gentle heat in a sand bath, or by bedding them in hot dung. The vapour of the vinegar assisted by the tendency of the lead to combine with the oxygen which is present, corrodes the lead, and converts the external portion of it into a white substance which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly until they are corroded through, and completely reduced to an oxyde; this is called *ceruse*, or white-lead. It is afterwards, bleached, ground, and saturated with linseed oil. It is then put into tubs resembling butter firkins, each containing about three hundred weight: in such tubs it is dispensed at the colour shops. But at such places it is frequently adulterated with powdered chalk, so that an experienced painter who is desirous that his work should retain its colour, prefers purchasing his lead at the works, where he is sure of having it pure. Lead improves by keeping, and all the best whites are performed by it when it is at least two or three years old. The Nottingham ceruse is most esteemed for house work when it is required to be finished in what is technically called flatting or dead white.

Litharge is employed by painters to render their colours more drying, and is composed of the ashes of lead, or a kind of dusky powder that first appears in its oxydation. When in this state it is called by the chemists a subcarbonate of lead, and is afterwards saturated with linseed oil to render it more drying.

Linseed Oil is obtained by pressure from the seed of flax; it is afterwards filtered to clear it of any of the feculæ of the seed, and then suffered to remain in tubs to precipitate and clarify. The more colourless the oil is the better, and this is greatly promoted by keeping, as linseed oil will by being kept a year or two deposit all its colouring particles, and be as transparent as water: the best painting is made with oil in this state. In Holland they whiten their linseed oil by a very simple process, which is said by them to answer every purpose to be derived from its age. They take an earthen pot well glazed, into which they put one-third of fine white sand and one-third of water with the linseed oil they wish to whiten; and after having covered the vessel with glass they expose it to the sun, taking care to stir it at least once a day. When the oil has become very white, it is left at rest during two days, after which it is taken away for use.

Of Drying Oils.—The substances most usually employed to produce them are the oxyde of lead, called litharge, plaster, and umber. The process consists in taking

taking of these several materials in the proportions as *follow*, viz. to one pound of oil add half an ounce of litharge with as much ceruse, umber, and plaster. The oil is boiled on these four drugs over a gentle fire, taking care to skim it from time to time; this matter so skimmed off is called by the house-painter smudge, or dryer; it is of a lead colour, and is used by him in his outside work, and sometimes mixed in the dark colours to render them more susceptible of fixing and drying. As soon as this scum begins to rarify and become red the fire is stopped, and the oil being left at rest gradually settles and clarifies. Linseed oil so prepared is vended at the colour shops under the name of boiled-oil. All the best house-painting is done with it.

Mr. Vanherman has lately laid before the Society of Arts, a method of rendering fish-oil applicable to painting; and it appears to make a good and cheap vehicle for colours exposed to the weather, though it dries but slowly. To thirty-two gallons of vinegar he adds twelve pounds of litharge and twelve pounds of sulphate of zinc, shaking the mixture well twice a day for a week. The mixture is then put into a tun of fish-oil, with which it is well shaken and mixed, and the next day the clearer part, about seven-eighths of the whole, is poured off. Twelve gallons of linseed oil and two of oil of turpentine are then added to the clear part, and this being well shaken together is left to settle for two or three days, when it will be fit to grind white lead and all fine colours in: these, however, are to be thinned for use with linseed oil and oil of turpentine. For cheap paints exposed to the weather, whiting and road dirt finely sifted are to be mixed with lime water to the consistence of mortar. To this composition may be added almost any pigment ground with the sediment of the prepared oil, in the proportion of one part to two of the lime water already used, and the whole is to be thinned for use, by adding to every eight pounds a quart of linseed oil and as much of a mixture of the prepared oil with lime water. The proportions of the mixture are not mentioned. If two ounces of litharge be added to a gallon of linseed oil and well shaken every day for a fortnight, and the clearer part mixed with half a pint of oil of turpentine be exposed to the sun for two or three days in shallow pans, Mr. Vanherman says "it will be as white as nut oil." If half a pound of frankincense be dissolved in a quart of oil of turpentine and added to a gallon of this bleached oil and white lead ground in oil of turpentine be thinned for use with the mixture, he asserts that it will be quite dry and void of smell in four hours.

Oil of Turpentine, or, as it is called, Turps, is in general use among us in house-painting, and is the ingredient by which the flatting, as it is termed, is performed. All the larch and fir trees furnish a resin known by the general name of turpentine. Commerce distinguishes several qualities according to its degree of goodness. The larch tree furnishes what is called *Venice Turpentine*; it is obtained by being made to flow from the trunk of the tree through holes made with an augur in which small pipes are fixed, that conduct the juice into buckets placed to receive it. This turpentine has a yellowish and limpid colour, a strong aromatic smell, and bitter taste. In Canada the peasants collect it from the fir tree by perforating the *sacs*, which contain it under the bark, with the point of a horn which is filled with this juice. It is afterwards distilled, in which it liberates an oil more or less volatile, according to the degree of heat employed. When the operation is done by a bath, a white, limpid, and odoriferous oil is obtained which is called essence of turpentine. The residue from this distillation forms the boiled turpentine of commerce. This is sold at the colour shops in the same way in which oil is, viz. by the gallon. This as well as the oil considerably improves by age: hence all painters in a large way of business keep it by them in quantities which enables them to depend on their work retaining its colour: a circumstance of no little importance in our mode of house-painting.

Of the Colours.—The colours used by painters may be classed as follows:

Red	Vermilion, Native Cinnabar, Red-lead, Scarlet-Ochre, Common Indian Red, Spanish-Brown, *Terra di Sienna*, burnt	Colour red, tending to Orange.
	Carmine, Lake, Rose-Pink, Red-Ochre, Venetian Red.	Colour Crimson tending to Purple.
Blue	Ultramarine, Ditto, ashes, Prussian-Blue, Verditer, Indigo, Smalt.	
Yellow	Kings-Yellow, Naples Ditto, Yellow-Ochre, Dutch-Pink, English Ditto, Light Pink, Gamboge, Masticot, Common Orpiment, Gall-stone, *Terra di Sienna.*	
Green	Verdigris, Crystals of Ditto, Prussian-Green, *Terra Verte*, Sap-Green.	
Orange	Orange-Lake.	

Purple	True Indian Red, Archil, Logwood Wash.
Brown	Brown-Pink, Bistre, Brown-Ochre, Umbre, Cologne Earth, Asphaltum.
White	White-flake, White-lead, Calcined Hartshorn, Pearl White, Troy White, Eggshell White, Flowers of Bismuth.
Black	Lamp-black, Ivory Ditto, Blue Ditto.

These embrace almost the whole of the colours employed by the house-painter, and which by experience he is enabled to mix in proportions to effect almost every tint.

Vermilion is a bright scarlet pigment, and is formed of common sulphur and quicksilver prepared for use by a chemical process. The best vermilion comes from China, where it is said the secret of making it alone is known. The Dutch pretend to have obtained it, and much of the vermilion at the shops is of their manufacture. It is so dear that the painters have recourse to every expedient to avoid using it, hence it is that the true Chinese pigment of this colour is seldom seen.

Cinnabar is a similar pigment, differing only from vermilion by a more crimson colouring.

Red-Lead, or minium, is lead calcined till it acquire a proper degree of colour by exposing it with a large surface to the fire.

Scarlet-Ochre is an earth with a base of green vitriol, and is separated from the acid of the vitriol by calcination.

Common Indian Red, is of an hue verging to scarlet, and is imported from the East Indies.

Venetian-Red is a native ochre rather inclining to scarlet; this is the pigment which is selected for the graining, as it is called by the house-painters, of doors, &c., in imitation of mahogany.

Spanish-Brown is a native earth, found in the state and of the colour in which it is used.

Terra di Sienna is a native ochre, and is brought from Italy in that state in which it is generally found. It is yellow originally, and in this state it is often made use of, and is accordingly placed among the yellow colours. It changes to an orange-red by calcination, though not of a very bright tint, for which property it is sought to produce a pigment of that colour.

Carmine is a bright crimson colour, and is formed of the tinging substance of cochineal with nitric-acid. It is not well calculated to mix up with oil, as its colour changes rapidly by exposure to the air and light.

Lake is a white earthy body, as cuttle fish-bone, the basis of alum or chalk tinged with some vegetable dye, such as is obtained from cochineal or Brasil wood, taken up by an alkali and precipitated on the earth by the addition of an acid.

Rose-Pink is a lake like the former, except that the earth or basis of the pigment is principally chalk, and the tinging substance is extracted from Brasil or Campeachy wood.

Red-Ochre is a native earth, but that which is in common use is coloured red by calcination, being yellow when dug out of the earth, and the same with the yellow ochre commonly used. This latter substance is chiefly brought from Oxfordshire, where it is found in great abundance.

Ultramarine is a preparation of calcined *lapis-lazuli*, which is, when perfect, of a brilliant blue colour, of an extremely beautiful and transparent effect in oil, and will retain this property with whatever vehicle or pigment it may be mixed. It is excessively dear and is frequently sold at the colour shops in an adulterated state.

Ultramarine Ashes are the residuum or remains of the calcined *lapis-lazuli.*

Prussian-Blue is a brilliant pigment; it is the fixed sulphur of animal or vegetable coal chemically combined with the earth of alum.

Verditer is the mixture of chalk with the precipitated copper, which is formed by adding the due proportion of chalk to the solution of copper made by the refiners in precipitating the silver from the nitric acid in the operation called *parting*, in which they have occasion to dissolve it in order to its purification.

Indigo is a tinging matter extracted from certain plants which are found in both the Indies, and from whence the Indigos of commerce are imported.

Smalt is glass coloured with zaffer, and afterwards ground to a powder.

Kings-Yellow is a pure orpiment, or arsenic coloured with sulphur.

Naples-Yellow is a warm yellow pigment rather inclining to orange.

Yellow-Ochre is a mineral earth, which is found in many places, but of different degrees of purity.

Dutch-Pink is a pigment formed of chalk, coloured with the tinging particles of French berries. It is not well adapted to work in oil by reason of its colour soon flying off.

English and light Pink are merely a lighter and coarser kind of Dutch pink.

Gamboge is a gum brought from the East Indies; it is dissolved in water to a milky consistence, and is then of a bright yellow colour.

Masticot, as a pigment, is flake-white or white-lead gently calcined, by which it is changed to a yellow, which varies in tint according to the degree of the calcination.

Orpiment is a fossil body of a yellow colour composed

posed of arsenic and sulphur, with a mixture frequently of lead and sometimes other metals.

Gall-stone is a concretion of earthy matter formed in the gall bladder of beasts. It is but little used.

Verdigris is an oxyde of copper formed by a vegetable acid: it is used in most kind of painting where green is required.

Crystals of Verdigris is the salt produced by the solution of copper or common verdigris in vinegar.

Prussian-Green is in composition similar to blue of the same name.

Terra Verte is a native earth; it is of a bluish green colour, resembling the tint called sea-green.

Sap-Green is the concreted juice of the buckthorn berry.

Orange-Lake is the tinging part of annatto, precipitated together with the earth of alum.

True Indian Red is a native ochrous earth of a purple colour, but so scarce as seldom to be met with at the colour shops.

Archil is a purple tincture prepared from a kind of moss.

Logwood is brought from America, and affords a strong purple tincture.

Brown-Pink is the tinging part of some vegetable of an orange colour precipitated upon the earth of alum.

Bistre is a brown transparent colour of yellowish tint.

Brown-Ochre is a warm brown or foul orange colour.

Cologne Earth is a fossil substance of a dark blackish brown colour, a little inclining towards purple.

Asphaltum is sometimes employed by the painters to answer the end of brown pink.

White-flake is a ceruse prepared by the acid of grape.

Troy White is simply chalk, neutralized by the addition of water in which alum has been dissolved.

Lamp-black is the soot of oil collected as it is formed by burning.

Ivory-black is the coat of ivory or bone formed by giving to them a great heat, all access of the air being excluded.

Blue-Black is the coal of some kind of wood burnt in a close heat where the air can have no access.

Such are the several colours employed by painters; they are all to be found in the colour shops both in a crude and prepared state. Preparing the colours consists in the first place of grinding them on slabs of porphyry till the particles are reduced to the finest imaginable state; this is done by saturating them with oil or water, according as the colour ground is to be used with either of them.

House-painting is known in the trade by the number of coats of paint applied, and the painting is divided into work in oil and what is technically called *flatting*. This latter description of work differs from the former only in the colour being mixed up with turpentine instead of oil. Good painting is known by the *fullness* and *solidity* of its appearance without any marks of the brush; whereas cheap painters care little about this. To give a fresh appearance, and get their work out of hand, and be paid, is their only concern.

In the division of house-painting, as understood between the surveyors and workmen, are as follow:—

Clearcole and finish, signifies that the work is to be done in the *cheapest way*, and the process of doing which consists in first dusting and cleaning what is to be painted, and stopping and filling-up all cracks and defects with putty. After which the whole is painted over with a paint prepared of whiting and size, which forms the ground for the *finish*, as it is termed. This finish consists of a coat of oil-colour prepared with lead. Where the work is not very dirty this kind of painting will answer every purpose, but it is by no means adapted for outside work.

Bringing forward, a term used by painters, applies to such new-wood or other work which may have been added to old wood-work; or in cases in which the old wood-work has been repaired, and, in consequence, partly replaned, the priming and painting such parts to form a ground for the colour, so as that it shall appear alike when finished, is the process intended by this term.

Stopping is no more than that the painter is to well fill up all the defects in the work he may have to paint, with putty.

Twice in Oil is simply that the work has been twice painted over.

Thrice in Oil, and Flat, signifies that the work has been done twice over in oil colours and once in colour mixed, or prepared in turpentine.

Three Times and Flat may be similarly explained, that is, three coats of oil colour and one of turpentine. This latter description of painting is generally that which is required to new wood-work.

The painter's tools are few in number, and they are found for the journeymen by the masters. They consist of a tool, or pound brush as it is called, which is composed of hogs' hair; this they use as a duster, until the ends of the hair of which it is composed are worn away, and become soft; it is then used in the colour, being better adapted to spread it evenly by such previous wear. The other brushes vary in size, as the mouldings and work to be painted do; the smallest are to paint over the bars of sashes, or draw out lines which are intended to be left of a different tint from the general tone of the other work.

In mixing up the colours for oil-painting, white-lead forms the base of all ingredients; this the colour-preparer modifies and changes by adding coloured substances to it, till it is tinged so as to produce a paint of the colour he wishes. All those colours which are derived from vegetable bodies have, at first being spread, a more brilliant effect than those of mineral ones; but no *vegetable* colour will long stand the combined effect of air and light; while the mineral colours, so exposed, remain unchanged. This defect in the vegetable colours is owing to that spontaneous oxidation or carbonization which is effected by the oxygen of the atmosphere

atmosphere on all vegetable matter to which it can operate upon freely. To make this phenomenon more obvious, the air occasions a slow combustion or burning to take place, which dissipates the lighter or hydrogenous particles of the colour, and turns to a state of charcoal those which remain combined in the paint; hence all painting made with colours obtained from vegetable bodies soon appear black and discoloured.

Graining is understood among painters to be the imitating of the several different species of scarce woods such as are used for the best articles of furniture, viz. satin-wood, rose-wood, king-wood, mahogany, &c. &c. Imitations of this nature, when well performed, are calculated to give a zest to painting: at Paris, every species of wood-work used in their houses, as a part of the building, is done in this manner. The dead-white so much in vogue amongst us is not practised there. To grain satin-wood a ground is previously laid, composed of Naples yellow and ceruse, diluted with oil of turpentine, this is spread very evenly over the work to be grained, and is then left a day or two to get fixed and dry. The painter then prepares his pallet-board with small quantities of the same yellow and ochre, with a little brown, having some boiled oil and oil of turpentine mixed together, to saturate the colours to be used in the operation. He is also provided with several different sized camels' hair pencils, and also with one or more *flat* hogs' hair brushes. When he has mixed the colours he spreads it over a pannel, or any other small part of the work, first, to see the effect of the tints, and if it suit what he is about to perform, he perseveres by doing a pannel at a time; and, in the instance of doors and other framing, the pannels are done first, and the margins round them afterwards. The flat hogs' hair brushes, by being dipped in the mixture of oil and turpentine, and drawn down the newly-laid colour, occasions the shades and grainings in it: this effect takes place in the colour from the brush supplying an excess of saturation to the colour it touches; and to produce the mottled appearance, the camels' hair pencils are applied, and when it is all finished, it is left to fix and dry, after which it is covered by a coat or two of good oil-varnish. The other fancy-woods are performed in a similar manner, the painter varying the colours to produce them only. Some of our painters are so expert at this kind of imitation, and also in that of marbles, as to prevent their easy detection, except by the touch. Among the best artists in this line now in practice in London, are a Mr. Harman of Chelsea, and Mr. Willement, of Green-street, Grosvenor-square. Such kinds of painting are well calculated to last a great many years by being occasionally re-varnished only. It is not greatly dearer than good work in the common way, but it will last *ten* times as long, without appearing to loose any of its freshness.

Ornamental Painting embraces the executing of friezes and the decorative parts of architecture in chiara-obscura, or light and shade on walls and ceilings. It requires, in the first place, a ground to be well painted of the tint it is proposed to remain, and exactly drawn into the width it is intended to be left on such a ground so formed. The ornament to be painted is to be drawn out neatly with a black-lead pencil, and then to be painted and shaded, to give it its due effect.

Such kind of painting is often painted on slips of paper, or Irish cloth, and pasted up afterwards; some artists also, to facilitate their work, and when the ornament is of a similar pattern all through, do it by what is termed *stinselling*; this method consists in drawing out a certain length of the pattern to be painted, very accurately on paper, and then pricking a large-sized needle in regular distances all round the pattern through the paper, which they afterwards lay smoothly against the wall to be ornamented and strike its outer surface, which has been pricked through with a small linen bag containing powdered chalk, the powder enters the apertures in the pattern, and fixes itself against the wall, exhibiting the exact outline of the ornaments which the painter immediately fixes by painting it on the wall; by this means a great saving of his time is accomplished. Some paintings in this manner are heightened with gold: this is performed after the ornament is painted-in, as it is termed, by the process known as Gilding in Oil.

Letter or Inscription Writing is performed by persons known in the trade as letter-writers. The process is similar to ornament painting, excepting the superior ability and taste required in the one, whereas the other is a mere mechanical operation. The letter-writer sketches out in pencil the words he has to write, and afterwards corrects the outline by the colour which he applies with a camels' hair pencil. When the letters are to be gilt, the process is similar, and as the letters are painted, they are covered with leaf-gold, and when completely covered it is left to fix itself by the drying of the painting on which it has been laid. After which, a sponge and water is used to clear away the superfluous gold; the whole is then covered by a coat of good oil varnish. Letter-writing is charged by the inch, viz. the height of one of the letters being taken, will, by being multiplied by the number on the whole inscription, denote exactly the quantity of inches which has been written. The price varies in as much as shadowed letters are a halfpenny an inch more than plain ones, and gilt letters are treble the price of either. *Two-pence* an *inch* is about the average price of inscription letters.

Painters' work is measured by the yard superficial, of nine square feet, and the painter is allowed to take his dimensions over and into every part where the brush has passed. Sash frames are valued at per piece, and sash squares at per dozen, as well as window bars, balusters of stairs, stay bars, &c. Painting done on new stucco is allowed one penny per yard more than when on wooden work, and colours are charged an additional penny more than when done in plain whites.

The

The painters' charges are regulated in London by the surveyors, and their regulations are made from an average of the price of the best materials of every kind; but painting is frequently offered to be done at from fifteen to twenty per cent. less than the price so regulated. But, perhaps, no branch of trade allows of greater description than painting, as oil and colours may be purchased of all degrees of purity: hence painting, like the gold of the jewellers, will be, in its quality, or fineness, as it is, viz. by the ratio of its alloy or adulteration.

PAPER-MAKING.

This art, as at present practised, is not of a very ancient date; paper made of linen rags appears to have been first used in Europe towards the beginning of the thirteenth century, but of its origin nothing can with certainty be affirmed.

The ancients, as substitutes for paper, had recourse successively to palm-tree leaves, to table-books of wax, ivory, and lead; to linen and cotton cloths; to the intestines or skins of different animals; and to the inner bark of plants. In some places and ages they have even written on the skins of fishes; on the intestines of serpents; and, in others, on the backs of tortoises. There are few plants but have at some time been used for paper or books, and hence the several terms, biblos, codex, liber, folium, tabula, &c., which express the different parts on which they were written, and though in Europe all these disappeared upon the introduction of the papyrus and parchments, yet, in some other countries, the use of them remains to this day. In Ceylon, for instance, they write on the leaves of the talipot: and the Bramin MSS. in the Tulinga language, sent to Oxford from Fort St. George, are written on leaves of plants. Hermannus gives an account of a monstrous palm-tree, which, about the thirty-fifth year of its age, rises to be sixty or seventy feet high, with plicated leaves, nearly round, twenty feet broad, wherewith they commonly cover their houses, and on which they also write; part of one leaf sufficing to make a moderate book. They write between the folds, making the character through the outer cuticle.

The paper which had been for a long time used by the Romans and Greeks was made of the bark of an Egyptian aquatic plant, called the papyrus, whence the name paper. According to the description which Pliny, after Theophrastus, gives us of it, its stalk is triangular, and of a thickness that may be grasped in the hand; its root is crooked, and terminates by fibrous bunches, composed of long and weak pedicles. The Egyptians call it Berd, and they eat that part of the plant which is near the roots. A plant, named papero, much resembling the papyrus of Egypt, grows likewise in Sicily; it is described in Lobel's Adversaria. Ray, and several others after him, believed it was of the same species; however, it does not seem that the ancients made any use of that of Sicily, and M. de Jussieu thinks they ought not to be confounded.

The internal parts of the bark of this plant were the only ones that were made into paper, and the manner of the manufacture was as follows:—

Strips, or leaves, of every length that could be obtained, being laid upon a table, other strips were placed across and pasted to them, by means of water and a press, so that this paper was a texture of several strips, and it even appears that, in the time of the Emperor Claudius, the Romans made paper of three layers.

Pliny also informs us, that the leaves of the papyrus were left to dry in the sun, and afterwards distributed according to their different qualities fit for different kinds of paper; scarcely more than twenty strips could be separated from each stalk.

The Roman paper received a size as well as ours, which was prepared with flour of wheat diluted with boiling water, on which were thrown some drops of vinegar; or crumbs of leavened bread, diluted with boiling water, and passed through a bolting-cloth, being afterwards beaten with a hammer. This account of Pliny is confirmed by Cassiodorus, who, speaking of the leaves of papyrus used in his time, says, that they were white as snow, and composed of a great number of small pieces without any junction appearing in them, which seems to imply necessarily the use of size. The Egyptian papyrus seems even to have been known in the time of Homer; but it was not, according to the testimony of Varro, till about the time of the conquests of Alexander that it began to be manufactured with the perfection which art adds to nature.

Paper made in this manner with the bark of the Egyptian plant, was that which was chiefly used till the tenth century, when cotton was used for making paper by pounding and reducing it to a pulp. This method, known

known in China some ages before, appeared at last in the empire of the East, yet we are without any certain knowledge of the author, or the time and place of this invention.

Father Montfaucon says, that cotton-paper began to be used in the empire of the East about the ninth century. There are several Greek manuscripts, both on parchment, on vellum, and cotton paper, that bear the date of the time in which they were written; but the greatest part are without date. From the dated manuscripts a surer judgment may be formed by comparing the writings of the age with those that are without any date. The most ancient manuscript on cotton paper with a date, is that in the king of France's library, numbered 2,889, written in 1050: another, in the emperor's library, that bears its date, is of the year 1095. But as the manuscripts without a date are much more numerous than those which are dated, Father Montfaucon, by comparing the writings, discovered some of the tenth century: among others, one of the king's library, endorsed with the No. 2,436. If the same search were made in all the libraries, both of the East and West, others, perhaps, might be found, of the same time or more ancient. Hence it may be judged, that this bombycine, or cotton paper, was invented in the ninth century, or, at latest, in the beginning of the tenth. Towards the end of the eleventh, or the beginning of the twelfth, its use was common throughout the empire of the East, and even in Sicily. About the same time, the empress Irene, consort of Alexis Comnenes says, in her Rules for the Nuns at a house which she had founded at Constantinople, that she left them three copies of the rule, two in parchment and one in cotton paper. Since this time, cotton paper was still more in use throughout the whole Turkish empire.

Chinese paper is of various kinds; some is made of the rind or bark of trees, especially the mulberry-tree and elm, but chiefly of the bamboo and cotton tree. In fact, almost each province has its several sorts of paper. The preparations of the paper made of the bark of trees, may be instanced in that of the bamboo, which is a tree of the cane or reed kind. The second skin of the bark, which is soft and white, is generally made use of for paper; this is beat in fair water to a pulp, which they take up in large moulds, so that some sheets are above twelve feet in length; they are completed by dipping them in alum water, which serves instead of size among us, and not only hinders the paper from imbibing the ink, but makes it look as if it were varnished over. This paper is white, soft, and close, without the least roughness, though it cracks more easily than the European paper, is very subject to be eaten by the worms, and its thinness makes it liable to be soon worn out.

The inventor of the linen-rag paper, whoever he was, is entitled to the gratitude of posterity, who are enjoying the advantages of the discovery. The art of printing would have been comparatively of little importance without having the means of procuring a proper material to receive the impressions: while the papyrus was the only kind of paper, it was impossible to have procured it in sufficient quantities to have made large editions of books, without which the great bulk of mankind would have for ever retained the ignorant barbarity of the dark ages; the cotton paper, though an improvement, was but a rude and coarse article, unfit for any of the nice purposes to which paper is now applied. The perfection of the art of paper-making consisted in finding a material which could be procured in sufficient quantities, and would be easy of preparation. Such is paper now in use, of which we shall endeavour to describe the manufacture.

A more common or economical substance could not be conceived than the tattered remnants of our cloths, linen worn out and otherwise incapable of being applied to the least use, and of which the quantity every day increases. Nor could a more simple labour be imagined than a few hours trituration by mills. The dispatch is so great, that it has been observed by a French writer, that five workmen in a mill may furnish sufficient paper for the continued labour of 3,000 transcribers. This was on the supposition of the process being conducted upon the old system of hand labour, but by the improved system of our modern mills, where the paper is produced in a constant and regular sheet by a curious machine, instead of the workman making sheet by sheet separately, a great portion of the labour is totally done away.

The operations of paper-making, as they succeed each other, are as follows:—

1st. The rags are washed, if requisite, and then sorted.

2d. They are bleached to render them white, but this is sometimes deferred to another stage of the process.

3d. They are ground, with water, in the washing-engine, till they are reduced to a coarse or imperfect pulp, called half-stuff, in which state the bleaching is sometimes performed; at other times it is bleached in the engine.

4th. The half-stuff is ground in the beating-engine, and water added in sufficient quantity to make a fine pulp, which being conveyed to,

5th. The vat, the sheets of paper are made by taking up a quantity of the pulp upon a mould of fine wire cloth, through which the water drains away, and the pulp coagulates into a sheet of paper; to take this off the wire is called *couching*.

6th. This sheet is put in a pile with many others, with a felt between each, and the whole is subjected to a strong pressure to press out the superfluous water.

7th. The sheets are taken out, the felts removed, and the sheets of paper pressed again by themselves for a certain time.

8th. The sheets are taken from the press and hung up, five or six together, to dry in the drying-loft.

9th. The paper is dipped into a tub of fine size, and pressed to force out the superfluity, after which it is dried

dried again; but, in printing-papers, this process is rendered unnecessary by sizing the stuff whilst in the engine, by adding certain ingredients.

10th. The paper now undergoes an examination of each individual sheet, and all knots and burs are removed, and bad sheets taken out.

11th. The dry sheets are packed in a very large pile, and pressed with a most immense force to render the sheets flat and smooth.

12th. The paper is taken out, parted, and pressed again; parting means, to take down the pile sheet by sheet, and make another without turning the sheets over; by this means new surfaces are brought in contact with each other, and the surface of the paper improved.

13th. The paper is now finished, and is counted into quires, folded, and packed up in reams for market.

The linen rags, used for making paper, being collected by itinerant merchants, are purchased by wholesale dealers or rag merchants, who, for the London trade, separate them into five sorts of white rags which they sell to the mills; they are denominated Nos. 1, 2, 3, 4, 5, according to their respective qualities. No. 1, called London superfine, being all linen, the remains of fine cloth, which not being so much worn as the coarser sort is used for making the finest paper. No. 5, is coarse canvass, which by bleaching may be brought to a good colour, but will not make paper of the strength and fineness of the finer sorts. The next sort rag bagging, a worse canvass, of which the bags are made for packing the rags. Coloured rags are generally cotton of all colours, except blue, which is selected for making blue paper only.

Superfine paper for writing or fine printing can only be made from Nos. 1, 2, and 3; Nos. 4 and 5 are appropriated for making an inferior paper called news, because used for news-papers; the coloured rags are only used for the inferior papers.

Woollen and silk rags are used for brown paper, but even for this purpose they should be mixed up with a large parcel of coarse linen.

Old paper may also serve for the same use, but the waste would be too considerable; whence it is rather reserved for pasteboard, in the manufacture of which the material is worked in less time, with less force, and with the same water. It will also lose much less. Besides paper that has been once sized, though passed through boiling water, still gives the pulp a viscidity which ought to be guarded against.

The rags when first brought to the mill, if they are very dirty, as the coarse sorts generally are, are washed in hot water by a fulling mill, such as is used by dyers for washing cloth. The rags being well dried are (if they have not been previously sorted by the rag merchant) delivered to women to sort and scrape them. These women are disposed of in a large room full of old linen, seated two by two on benches with a large chest or box divided into five cases before them, for containing the five different sorts of rags as beforementioned. Each has a piece of pasteboard hung from her girdle and extended on her knees, upon which, with a long sharp knife, she unrips seams and stitches, and scrapes off all filth. Whatever can be used after being well shaken is distributed into the three cases according to the degree of fineness, and the women throw the rest at their feet. Those manufacturers who choose to be more exact in their sorting, have six cases for six different sorts of rags; the superfine, the fine, the seams, and stitches of the fine; the middling, the seams and stitches of the middling; and the coarse, without including the very coarse parts, which are reserved for making brown paper.

Some manufacturers are persuaded that the labour of the sorters is never sufficiently exact, and think that the hems and seams should be kept apart; that the coarseness of the cloth should be considered, and that the cloth made of tow should be separated from that made of the longer slips; cloth of hemp from cloth of flax; and, lastly, that the degree of wearing in the cloth should be attended to; for if rags which are almost new should be mixed with those that are much worn, the one will not be reduced to a pulp in the mill, whilst the other will be so attenuated as to be carried away by the water, and pass though the hair-strainer, and hence there must be a considerable waste in the work, a real loss to the manufacturer, and even to the beauty of the paper, for the particles already carried off, are perhaps those which give it that smooth and velvet softness of which it is often deficient.

This is not all, for the pulp of uneven tenuity produces those cloudy papers, wherein are seen by intervals parts more or less clear, and more or less weak, occasioned by flakes assembled on the mould in making the paper not being sufficiently tempered and diluted to incorporate with the more fluid parts.

It would, therefore, be very advisable to have the different qualities of the cloths milled separately, as also the hems and threads of the stitching; because sewing thread being never so much worn as that of the cloth, and being not so easy to be reduced, forms filaments in the paper. When the rags unequally disposed for trituration have been milled apart, then such different pulps may be mixed together without inconveniency, which will be found homogeneous, each having been worked during the time that was necessary, according to the state of the rag. Without this precaution the finest particles will be always lost, and of course the quality of the paper will be altered by an excess of the coarsest.

This great precaution in the sorting of rags is of course very expensive; but there is no doubt of its producing a total difference, in the beauty of the paper, without hurting its goodness. It will besides be attended with the advantage of mixing a pulp, which is supposed to form the strength of the paper with another that gives it softness and lustre; and thus these two qualities may be united which hitherto existed separately.

The

The greatest modern improvement in paper-making is the bleaching the rags. This enables the manufacturer to produce the finest paper, in point of colour, from any kind of rags. He has, therefore, only to find such materials as will make a paper of a strong texture and a fine even surface, knowing he can produce colour at pleasure.

The bleaching is conducted in different methods, either bleaching the rags immediately after they are sorted, bleaching them in the state of half-stuff, that is, after it has been once ground in the washing engine, or while they are in the engine. For the first of these methods Mr. Campbell had a patent in 1792. His method is very similar to the process of bleaching of cotton thread. The apparatus consists of a receiver or chamber made of wood to contain the rags to be bleached; it is of a cubical form, and the joints made air tight; it is provided with several retorts, which being filled with a mixture of manganese, with two-thirds its quantity of sea salt, and a quantity of sulphuric acid equal to the salt, will, when moderately heated by a small sand-bath furnace, throw into the receiver a gas which quickly discharges any colour the rags may contain. The patentee directs that the rags should, before they are put into the receiver to be bleached, contain about their own weight of water, the superabundant water being pressed out; the rags should then be opened by a machine, called by the cotton manufacturers a devil, or some machine of that nature: they are to be distributed in the receiver in layers, spread in frames so that they will not come in contact with each other, or the rags may be placed in the body of the receiver, and have stirrers or agitators provided to expose every part of them to the action of the bleaching gas. After the process, which must be concluded as soon as ever the rags are sufficiently bleached, lest the gas should act upon and injure their quality, they are to be washed in water, and will be ready for the mill; here they are ground and reduced with water to a fine pulp till every individual fibre of the rag is separated.

The paper-mill is represented in the *Plate*, Paper-Mill. Here *Fig.* 1 is a front and *Fig.* 2 a side elevation, the same letter expressing the same part in both. AB is the great water wheel, giving motion to the whole on its shaft or axis C; a crown, or face wheel, DD is framed, and gives motion to the pinion G; this is fixed on the lower part of a vertical axis E F, which goes up into the upper room of the mill, and has two face wheels I and K fixed upon it; these actuate two pinions L M, upon the end of the spindles of the two engines N and O, where the rags are ground. W, *Fig.* 1, is a wheel turned by the teeth of the great wheel DD; the axis of this wheel is formed into a triple crank *v*, *w*, *x*, which gives motion to the three pumps, by means of levers or beams *y*, *z*, *y*, which cannot be fully seen in the figures, but may be easily imagined. These pumps raise up a constant stream of fair water, which is necessary to be kept running through the rags in the engine to wash away the dirt separated from them in the grinding. By the arrangement of the cog wheels, the pinions LM and cylinders of the engines are caused to revolve at the rate of 150 times per minute, when the water wheel moves with its proper velocity. The internal construction of the engine is explained by the remaining figures of the plate. *Fig.* 3, is a longitudinal section, shewing the cylinder in action; *Fig.* 4, a plan looking down upon it; *Fig.* 6, the cylinder separate; N and O in *Fig.* 1, represent a large cistern or vat of an oblong figure, with the angles removed, as shewn by *Fig.* 4; it is lined with lead inside, and divided in the middle by a partition *e f*, *Figs.* 3 and 4. On the front and back of the engine two short beams TT, *Figs.* 2, 4, and 5 are bolted; they have long mortises through them to receive tenons at the ends of two horizontal levers S S, which rise and fall in bolts in one of the beams T as centres; the front one of these beams, or that nearest to the cylinder R, is capable of being elevated or depressed by turning the nut of the screw *r*, which, as shewn in *Fig.* 5, is fixed to the tenon of S, and comes up through the top of the beam T, upon which the nut takes its bearing. Two brasses are let into the middle of the levers S S, and form the bearing for the spindle of the engine to turn upon. R is the cylinder made of wood and fixed fast upon the spindle; it has a number of knives or cutters fixed upon it, parallel to its axis, and projecting from its circumference about an inch: *e*, *Fig.* 3 and 4, is a circular breasting, made of boards and covered with sheet lead, which fits the cylinder very truly and leaves but very little space between the teeth and breasting. An inclined plane leads regularly from the bottom of the engine trough to the top of the breasting, at the bottom of the breasting beneath. The axis of the cylinder, a block *a*, *Fig.* 3, is fixed, it has cutters of the same size and exactly similar to those in the cylinder, which at all times of the process pass very close to the teeth in the block, but do not touch. This block is fastened by a dove-tail fixed in the wooden bottom of the breasting; it comes through the woodwork of the chest, and projects a small distance, on the outside of it, and is kept up to its place by a wedge, so that by withdrawing this wedge the block becomes loose, and can be removed to sharpen the cutters as occasion requires. The great velocity of the cylinder draws the rags, with which the engine trough is filled between the cylinder and the cutters in the block *a*, and by this they are cut in pieces; then by the rapid motion of the cylinder the rags are thrown over the top of the breasting, and they run down the inclined plane, and passing round the partition *e f* come to the cylinder again, so as to be repeatedly cut till they are reduced to a pulp. The screw *r* is used to raise or lower the cylinder, and cause it to cut finer or coarser by enlarging or diminishing the space between the cutters in the block and those of the cylinder. These cutters act in the same manner as a pair of scissars cut, the teeth of the cylinder being as before-mentioned parallel to the axis of the cylinder, and those of the block are placed rather inclined to them, so that the teeth of the cylinder come

come first in contact with the cutters of the block at one end, and then successively the contact proceeds along to the other end, so that any rags interposed between them are cut in the same manner as they would be between the blades of a pair of shears; sometimes the plates or cutters in the block are bent to an angle in the middle instead of being straight and inclined to the cylinder; in this case they are called elbow plates, and of course the two ends are both inclined to the axis of the cylinder in an opposite direction; in either case the edges of the plates of the block cannot be straight lines, but must be curved to adapt themselves to the curve, which an inclined line traced on the cylinder will of course have. The plates of the block are united by screwing them altogether, and their edges are bevelled away on one side only. The cutters of the cylinder are fixed in, as shewn in *Fig.* 7; here R is the cylinder, formed of a solid piece of wood, and having grooves cut on its circumference parallel to its axis; each of these grooves has two cutters put into it, and a fillet of wood is driven fast in between them to hold them in; the fillets are kept in by spikes driven into the solid wood of the cylinder. A cover is put over the cylinder to prevent the water or rags being thrown out of the engine by its great velocity; it is a square box, *g h k i*, *Fig.* 3 and marked P, *Figs.* 1 and 2, it has two small troughs, *k* and *i*, coming through the sides of the box; at *m m* are two hair or wire sieves sliding in grooves made in each side of the box. The cylinder as it turns throws a great quantity of water and rags up against these sieves; the water goes through them and runs down into the troughs at *k* and *i*, and from thence into the ends of the leaden pipes *p p*, *Fig.* 2, by which it is conveyed away; *n n*, *Fig.* 3, are grooves for two boards, which when down in their places cover the hair sieves and stop the water from going through them. A considerable part of the rags thus thrown up by the cylinder passes quite over it, and goes down under it again. The water is brought to the engine by a pipe from the pump; this pipe delivers it into a small cistern adjoining and communicating with the engine; the pipe has a cock to stop the entrance of the water when required; the exit of the foul water is, as before-mentioned, made by the cylinder throwing it up into the troughs *i* and *k*. The two engines N and O are placed at different levels as shewn by *Fig.* 1, the bottom of N being higher than the top of O; the latter is called the *washer*, where the rags are first worked coarsely with water running through them, to wash and open the fibres of them, which after washing are called half-stuff, and are then let down into the beating engine O, here they are ground and reduced to a finished pulp.

The proper management of the rags while in the mill, is a great part of the art of the paper manufacturer; and for this no rule can be given, as it wholly depends upon the material he has to work, and the article he intends to produce from it. For making superfine paper, the following may be described as the established system of manufacture for the London market: one hundred weight of the best white rags, called No. 1, is put into the washing engine, and the cock opened to let a considerable stream of water run through it. The screw of the cylinder is adjusted to raise it up, so that its teeth do not actually touch the teeth of the block: the rags are not therefore cut, but rather rubbed in a violent manner, so as to open and expose every fibre to the action of the water, that it may carry off all dirt; this gentle washing continues for a quarter of an hour or twenty minutes, when the cylinder is *laid down*, that is, the screw is turned back till the cylinder is let down upon the cutters of the block, and rests its weight upon them; in this state they begin with a most tremendous noise and vibration to cut the rags into pieces; this is continued for about four hours, by which time the engine will come to work very steadily and with less noise, because the rags are cut into pieces and chopped up very much, though not yet reduced to a pulp. The bleaching now commences, if it has not been done in the first stage upon the rags. To bleach the stuff in the engine they stop the water from running in, and throw into the engine a quantity of bleaching salt, or muriate of lime; for fine rags one or two pounds, more or less, are used according to circumstances; the two sliders, *n n*, *Fig.* 3, are put down in the cover of the cylinder to prevent the water getting away, and in this state the engine is worked about an hour for the bleaching. During this time the rags lose their colour, but this does not colour the water, though it is rendered rather white and milky by the salt. The very best rags, when first put into the engine, are of a very yellow and dirty colour, but they become by the bleaching a very perfect snow white. The cylinder is usually raised up a very little during the bleaching; which being concluded, the water-cock is opened again, the boards *n n* removed, and the washing continued about an hour to wash the salt away. This concludes the operation, and the half-stuff, as the rags are now called, is let off into a basket which suffers the water to drain through it: or if the manufacture is proceeding with dispatch, and every thing is ready, it is let off into the beating-engine at once; here the stuff is worked for about five hours with a sufficient quantity of water to make a pulp; in this affair great judgment is required as it materially influences the quality of the paper; the water is not suffered to run through the beater, as in the other engine. The only difference between the two engines is the firmness of their teeth. The cylinder of the washer has twenty grooves in it, each containing two bars or teeth, as shewn in *Fig.* 7, but the beater has three in each, so as to have sixty teeth in all. The beater is made to turn with a greater velocity than the other; the pinion L, *Fig.* 1, which turns the beater having only twenty teeth, while the other, M, has twenty-two. This greater velocity and number of teeth in the beater cause the strokes of the several knives passing by each other to be so rapid that they produce a coarse musical note or humming, which may be heard to a great distance from the mill; but the washer being

coarser and less rapid, produces the most horrible growling which can be conceived, and is so violent as to shake the whole building.

In many small mills, which have only a local trade for the supply of the surrounding country, and where perhaps there is a deficiency of water, they only use one engine both for washing and beating, as it will do for either purpose; but the mills near London, chiefly at Maidstone in Kent, have two, three, or even five engines. These require an immense body of water to turn them, for there is a considerable force required to turn the cylinder, and with so great a velocity it becomes very great. The stuff when finished is conveyed to a general receptacle called the stuff-chest, where it is kept till wanted to be made into paper, for the engines work day and night, though the making the paper, as it requires many workmen, is of course only carried on in the day-time. The implements employed in this department of the manufacture are as follows: the *vat* with its *stirrer*, the *moulds* and *deckles*, the *felts*, the *vat press*, and another press similar to it for giving the paper a second pressure.

The vat is made of wood in the form of a tub, and generally about five feet in diameter and two and a half in depth. It is kept at a proper temperature by means of a grate introduced at a hole in the side, and surrounded on the inside of the vat with a case of copper. For fuel to this grate charcoal or wood is used, and frequently to prevent smoke the wall of the building comes in contact with one part of the vat, so that the fire has no communication with the place where they make the paper. Every vat is furnished on the upper part with planks, enclosed inwards, and even railed in with wood to prevent any of the stuff from running over in the operation. Across the vat is a plank pierced with holes at one of the extremities, and resting on the planks which surround the vats. This is used to rest the mould upon when a sheet of paper has been made. In different mills two methods are made use of to mix up the stuff and water with which the vat is filled, and keep it in such an agitation as will prevent any coagulation or subsedence of the pulp, which would render the paper flaky and the different sheets of unequal thickness; in one, two instruments are employed to mix them, one of which is a simple pole, and the other a pole armed with a piece of board, rounded and full of holes. The operation of stirring is repeated as often as the stuff falls to the bottom. In the principal paper mills for making writing paper, they use for this purpose what is called a hog; which is a machine within the vat, that by means of a small wheel on the outside is made to turn constantly round, and keep the stuff in perpetual motion. When the stuff and water are properly mixed, it is easy to perceive whether the previous operations have been complete; for if the stuff floats close and in regular flakes, it is a proof that it has been well worked in the engine.

The mould is a square frame or box made of well seasoned mahogany, and covered at the top with wire. In the old way, the wires were disposed in parallel rows, with others across to strengthen them; this may be readily understood from the examination of a sheet of paper. But the modern paper is chiefly made of wool wire, which is exactly like cloth. The wire cloth is made larger than the intended sheet of paper, and turned down over the sides of the frame; the size of the sheet is determined by a square frame of mahogany bound with brass; this, which is called the *deckle*, when placed upon the wire of the mould forms a shallow dish or mould, in which a quantity of the pulp is taken up, and by the draining through of the water the pulp is left in a sheet upon the wire, therefore this frame is necessary to retain the stuff of which the paper is made on the cloth; it must be exactly adapted to the wire cloth of the mould, otherwise the edges of the paper will be ragged and badly finished. The wire cloth of the form is varied in proportion to the fineness of the paper and the nature of the stuff.

The deckle is moveable, and only held upon the mould by the workmen grasping the mould and deckle together in both hands at the opposite sides, so that the deckle being removed the sheet of paper may be taken up from the wire by applying the mould upon a piece of felt; it is then pressed with a felt between each sheet. The felts are pieces of woollen cloth spread over every sheet of paper, and upon which the sheets are laid to detach them from the wire of the mould; they prevent them from adhering together and imbibe part of the water with which the stuff is charged, and transmit the whole of it when placed under the action of the press.

The two sides of the felt are differently raised, that to which the hair is longest is applied to the sheets which are laid down, and any alteration of this disposition would produce a change in the texture of the paper.

The stuff of which the felts are made should be sufficiently strong, in order that it may be stretched exactly on the sheets without falling into folds, and at the same time sufficiently pliant to yield in any direction without injury to the wet paper. As the felts have to resist the reiterated efforts of the press, it appears necessary that the warp be made strong of combed wool and well twisted. On the other hand, as they have to imbibe a certain quantity of water and to retain it, it is necessary that the woof be of carded wool, and drawn out into a slack thread. These are the utensils together with the presses which are used in the apartments where the sheets of paper are formed.

Three workmen are employed in the operation of making the paper, which they manage thus; the first called the dipper, stands in a nitch or hollow part of that kind of ledge or table which goes round the circumference of the vat; he holds a mould in both hands by the two extremities with the deckle, applied exactly over the mould as if only one piece; then inclining it a little towards him he dips it into the vat and brings it up again in a horizontal position. The superfluous part of the pulp flows over on all sides, and the quantity thought sufficient is shaken gently from the right to the left, and

and up and down horizontally until it is equally extended over the whole surface of the mould. These two motions are also accompanied by a slight shake, that serves to fix and stop the sheet as the water drains through the wire; and then the parts of the pulp uniting, the mould is immediately laid on the edge of the vat, the deckle taken off, and the mould made to slide along the board which is laid across the vat to the part where the sheet is to be *laid* or taken off. This board which is but two inches in breadth where the sheet is laid is nothing more than a deal board, which runs along the length of the vat, and is pierced with several holes at the broad extremity for letting the mould drain into the vat.

The dipper taking the deckle off the first mould, places it immediately on the second which is given him for dipping it immediately in its turn, and the second workman called the coucher, taking the mould on the board that runs across the vat, with the left hand raises it gently and lays it in an inclined position against one or two small pins which are driven into the board on the edge of the vat. In this condition the mould remains two or three seconds of time for draining into the vat, whilst the coucher extends a felt on which he applies the mould to take off the sheet, which being done he returns the mould to the dipper.

These operations are performed in so short a time, that seven or eight sheets of a middling size can be made in a minute; but it would be advisable to proceed more slowly, as no doubt the paper would be better made, and of a stronger consistence.

The dipper should be attentive in distributing the matter on the mould to reinforce the corner he is to take hold of, in raising and extending the sheets; for without this precaution he would break a great many. If he also takes up too much matter with his mould, if he does not equally extend it, or if he strikes his mould against the drainer, in all these cases, the matter is accumulated in certain parts of the mould, which produces something like ridges in the paper; or, if he lets the matter rest on the mould, and does not distribute it immediately, there will be parts of unequal thickness. When the vat is too hot, the stretching out of the sheet will be ill performed, because the water evaporates too soon over the mould. Add to this, that, in letting the matter run towards one of the edges, by not giving his arm a regular motion, he may form a feather-edged paper, which may likewise happen if he does not extend his stuff sufficiently; if the vat be too hot, if the fecula of the pulp is too crude, and does not run well; if his arms are too stiff, and if he gives a bad shake, or if the mould be ill made. An indented sheet happens by not taking off the deckle properly, or by the fault of the felts having stitches, seams, and selvages in them.

In examining a sheet of paper, before the light, a greater opacity is seen on both sides of each brass wire than towards the midst of the space. This thickness is occasioned by the pulp, which the motion of the mould could not distribute, being stopped by the wires, or the manicord, that serves to string them. This defect is completely remedied by the improvement of weaving the wire of the mould like cloth, but a prejudice still prevails in favour of the old paper with lines, which obliges manufacturers still to make it, though by no means so fine or good as the wove. In order to avoid drops of water, which, if they fall upon the paper will make disagreeable spots, the mould should be laid gently, and raised readily; and, as often as the coucher returns his mould to the drainer, he ought to be careful to shake his hands behind him, for, without this precaution, his fingers, which are wet, would drop upon the sheet already laid, whilst he is covering it with the felt. If he is also too quick in laying, the air, detained and compressed under the sheet, occasions a bloating, and makes some parts more clear than others.

The coucher having taken off the several sheets from the mould as fast as they are made, lays them one by one in a pile under the press, with the felt between each individual sheet, until they have, in this manner, made six quires of paper, which quantity is called a post, and contains one hundred and forty-four sheets. When the last sheet of the post is covered with the last felt, the workmen about the vat assist each together to submit the whole heap to the action of the press. They begin, at first, to press it with a middling lever, and, afterwards, with a lever fifteen feet in length; this operation expresses the water and thus gives the paper a strength which it did not possess before. The vestiges of the protuberances made by the wires of the mould, are altogether flattened, and, of consequence, the hollows opposite to them disappear also; but the traces formed by the interstices of the wire, in consequence of their thickness, appear on both sides, and are rounded by the press.

The business of the third workman, called the lifter, begins after the operation of the press, and consists in taking the sheets off the felts (for they are caused to adhere to them by the action of the press), and then making the sheets up in a second pile: but if the coucher works too fast, and the lifter finds himself hard pressed, he cannot stretch out his sheets exactly upon one another, so as to make a neat and compact pile, for this is very necessary to make the paper of a regular and equal thickness, when it is put under a second press, which is done as soon as several of the piles are completed, and can be collected together; this second pressure being made with all the sheets in contact with each other expresses a great quantity of water from the paper, and gives the sheets a very considerable strength; it also tends to take out those freckles in the surface of the sheets, which were occasioned by the impression of the felt; though it is necessary to have felts in the first pressure, because the paper is then so wet that it would be pressed into a solid mass if the sheets touched each other. The paper remains in the second press as long as it can, until another pile is made ready by the lifter, when it is taken out and the sheets carried to the drying-house.

When

When the sheets are very thin, and it is found after the second pressure that they are formed by a fecula which is still saturated with a great deal of water, so that they have little consistence, it is probable that the second press has so joined them to one another, that it is difficult to separate them; and, indeed, they cannot well be taken off, one by one, without tearing a great number; but, happily, this separation, sheet by sheet, is not necessary for drying, so that seven or eight may be taken together, which is called forming the pages; sometimes, also, a less number may do when the paper is of a large size, but never less than three sheets are hung up together. It is of more importance than we are at first aware of, that the sheets should remain, as it were, pasted several of them together; if they were single, and one by one, they could not resist the moisture of the size, yet this moisture is sufficient to facilitate their operation; and, to hinder their separating, when they are hung up to dry, they should be so placed that the pages may receive the wind in the surface and not in the sides and edges.

The drying-lofts are very extensive apartments, usually the upper parts of all the buildings of the mill; the sides are formed by loffer boards, which are a kind of lattice, or boarding, which can be opened and shut to admit more or less air at pleasure. The sheets are taken up upon a piece of wood like a T, and hung upon hair lines, stretched across large horizontal wooden frames, called tribbles; and then, as they are filled, are lifted up between upright posts, to the top of the room, and retained by pegs put in the posts; then another frame being filled, is put up in its turn, and so on, till the loft is filled from top to bottom.

Mr. Bramah has made an improvement on this method, which enables women or children to perform the business of the drying-house instead of men, and adds considerable facility to the process of hanging and re-hanging the sheets. Instead of using tribbles, he has a proper number of frames, made of wood, mounted with leaves, to represent so many frames or clothes' horses, similar to those used by any common laundress, but of a length proportioned to the dimensions of the drying-house, which may be divided into two or more rows, so as to leave room and proper aisles or passages for the convenience of the operators to hang and re-hang the sheets; and the height of the frames may be equal, or nearly equal, to one half the story in which they are fixed. They are stationed at proper distances from each other by means of upright posts with grooves fitted to the frames, so that each may slide vertically up and down, by means of lines and pulleys affixed to each, just like sash windows that are double hung; so that while one of the frames is sliding up to touch the ceiling of the building with its upper edges, the alternate one may be depressed till its lower edge, or the paper which hangs upon it, may come nearly in contact with the floor. By this means children can reach to hang the paper, and can afterwards elevate the frames to their proper height in the loft.

The paper, when dry, is carried to an apartment where it is sized; this is done by dipping each page, that is, each bundle of thirty-four or thirty-five sheets, which have been dried together, into a vat, containing a weak size. This is made from shreds and parings got from tanners, curriers, and parchment-makers; all the putrefied parts, and the lime, are carefully separated from them, and they are enclosed in a kind of basket, and let down by a rope and pulley into the caldron. This is a late invention, and serves two valuable purposes. It makes it easy to draw out the pieces of leather when the size is extracted from them by boiling, or easy to return them into the boiler if the operation is not complete. When the glutinous substance is sufficiently extracted, it is allowed to settle for some time, and it is twice filtered before it is put into the vat where they dip the paper. Immediately before the operation, a certain quantity of alum is added to the size. The workman takes a handful of the sheets, smoothed and rendered as supple as possible, in his left hand, dips them into the vat, and holds them separate with his right, that they equally imbibe the size. After holding them above the vessel for a space of time, he sizes on the other side with his right hand, and again dips them into the vessel. When he has finished ten or a dozen of these handfuls, they are submitted to the action of the press, from which the superfluous size is carried back into the vat, by means of a small pipe. The vessel in which the paper is sized is sometimes made of copper, and finished with a grate, to give the size, when necessary, a due temperature, and a piece of thin board or felt is placed between every handful as they are laid on the table of the press.

After the sheets are sized and pressed they must be quickly separated from each other, to prevent their adhering together, but it is to be remembered that the size is an extremely weak solution, so that the sheets will be in no danger of adhering, until they are dry. In some of the most improved mills the sizing is performed in a machine, consisting of a large square vat, or wooden cistern, containing the size; in this a strong screw press is situated horizontally, the side beams of the press forming the outsides of the vat, and the screw works through a tight collar of leather. The press being open, the sheets of paper are suspended on lines, stretched in a frame, similar to those on which they are dried, and this is let down to immerse them in the size; and, after remaining a proper time, the screw of the press is worked, and the sheets thus gathered up into a close parcel; then the lines being withdrawn, a strong pressure is given, and the paper, when taken out, is finished ready to be hung up again to dry. By this means the paper is sized very equally, whereas, in the old method of tub-sizing, some sheets drained off more size than others, and rendered them unequal as well as making marks in them.

The operation of sizing is very expensive; but, for printing papers, and some others, it may be dispensed with. In this case, a small quantity of oil mixed with alum

alum, pounded very fine, is thrown into the beating-engine towards the end of the process. About a pint and a half, or less, is sufficient to give the paper a proper quality for printing, and is rather better than tub-sizing. Powder blue is also put into the engine to give a bloom to the paper.

When the paper is sufficiently dry, it is carried to the finishing room, called the *Saul*, where it is pressed, selected, and examined, by women, who remove all damaged and imperfect sheets; it is then put into the dry press, and squeezed with a most immense force, to render the paper flat, and give it a good surface. The lever of this press is fifteen or eighteen feet long, and ten or twenty people are employed at the last to work it, though they sometimes use *Sampson;* that is, a windlass like a crane, with which they purchase the lever of the screw. The dry press is generally large enough to hold two packs of ordinary paper side by side. The *Saul* is surrounded by the dry presses, often twenty or thirty, but one windlass serves them all. The paper remains under pressure as long as the demand of the mill will admit, but while it is in this operation it is parted, once, twice, or even three times: to do this, the heaps are carried back to the table, and the whole turned sheet by sheet, in such a manner that the surface of every sheet is exposed to a new one, and in this situation they are again brought under the press. It is in conducting these two operations of parting and pressing sometimes four or five times, or as often as the nature of the paper requires, that the perfection and finish of the finest writing and drawing-paper consist. If the stuff is fine, or the paper slender, the parting is less frequently repeated. In this operation, it is necessary to alter the situation of the heaps, with regard to one another, every time they are put under the press; and, as the heaps are highest in the middle, to place small pieces of felt, which will bring all parts of the pile to an equal pressure.

Mr. Bramah's ingenious hydrostatic-press is most admirably adapted for dry-pressing the paper. This press has no screw, but, in lieu thereof, a piston or plunger, fitted accurately into a chamber, or barrel of cast iron, by collars of leather; a small force-pump is situated near to the press, and water is injected by it into the great chamber, and the piston is thus expelled from it; at every stroke a quantity proportioned to the quantity of water injected, and this presses up the board, or follower of the press, with a power in proportion to the relative diameters of the pump and the piston.

The bottom of the cylinder must be made sufficiently strong, with the other parts of the surface, to resist the greatest strain which can ever be applied to it; the pipe from the forcing-pump communicates with the cylinder at the bottom, and the pump has, of course, valves to prevent the return of the water.

Now, suppose the diameter of the cylinder to be twelve inches, and the diameter of the piston of the small pump, or injector, only one quarter of an inch, the proportion between the two surfaces or ends of the said pistons will be as 1 to 2,304; and the intermediate space being filled with water, which is an incompressible fluid, any force applied to the small piston will operate upon the other in the above proportion, viz. as 1 to 2,304. Suppose the small piston, or injector, to be forced down, when in the act of forcing or injecting, with a weight of twenty hundred, which can easily be done by means of a long lever, the piston of the great cylinder would then be moved up with a force equal to twenty hundred weight multiplied by 2,304, or 2,304 tons.

In a screw-press, of a fine thread, it requires nearly as much labour to unscrew as to screw it down, an evidence of the enormous friction of a screw when acting against a great pressure; but the hydrostatic-press only requires a cock to be opened to let out the water from beneath the piston, which then descends quickly by its own gravity, or the elasticity of the substance under the pressure. The greatest convenience of the hydrostatic-press is, that the power can so easily be transmitted to it from any distance, and in any direction, by means of pipes conducted along in situations, where all other means of conveying the motion would be complicated and expensive in the extreme. Thus, in a large paper-mill, an injecting pump may be kept in constant action by the water-mill, and inject water into an air vessel, from which pipes are conducted to presses in all parts of the mill, and by simply opening a cock at any press, the required pressure will be instantly given by the elasticity of the confined air operating on the enlarged surface of the piston of any press. The air vessel has, of course, a safety-valve to allow the escape of the water, when the pressure becomes so great as to endanger the rupture of any of the vessels; for it is to be observed, that the power of this principle is irresistible when the pump is worked by a mill, and will burst any vessels without the least appearances of strain on the moving parts of the pump. To avoid the necessity of having such a number of presses for the dry-work of a mill, Mr. Bramah, instead of more presses, proposes to use a considerable number of another kind of apparatus called retainers, which consist of a top and bottom bed, of wood or metal, of sufficient strength to resist the re-action of the paper, when the press is slackened from its severest squeeze, and to retain it, in its most compressed state, for any required length of time, after the grasp of the press has been finally withdrawn. In these retainers vertical bars are fixed at the corners of the lower bed, passing through the holes in the upper one, and have each several holes to receive wedges or keys; by which the upper bed of the retainer is confined to preserve the state into which it has been pressed, notwithstanding any efforts of the paper or felts to expand to the space they originally occupied. These retainers are mounted upon wheels, applied to the lower boards, in the manner of a truck, and a railway is laid which goes through the press, so that the paper may be piled upon the trucks; the top board is then put on, and the whole wheeled

wheeled into the press, and the operation being finished, the retainer is made fast; the press is slackened, and the whole is wheeled forwards, leaving the press vacant for the reception of another retainer.

After the dry-pressing, the paper is finished, and only requires to be assorted into different lots, according to its quality and faults; after which it is made up into quires. The person who does this must possess great skill, and be capable of attention, because he acts as a check on those who separated the paper into different lots. He takes the sheets with his right hand to fold and examine them, laying them over his left arm till he has the number requisite for a quire; then brings the sides parallel to one another, and places them in heaps under the table.

The paper is afterwards collected into reams, of twenty quires each, packed up for the last time, and put under the press, where it is continued for ten or twelve hours, or as long as the demand of the paper-mill permits.

A great revolution has been recently made in the art of paper-making, by the adoption of machinery for fabricating it from the pulp, and, at one operation, pressing it between the felts, and rendering it fit for the second pressure, by which an immense saving of labour is made, and the quality of the paper improved. Messrs. Fourdrineer's have a patent for these machines, of which they have erected great numbers in different parts of the kingdom. Their construction is extremely curious and not easily explained without drawings. A wire cloth, of many yards in length, is used; its ends being sewed together, and it is extended horizontally between two rollers, so as to represent a table, which, by the revolution of the rollers is in constant motion; at one end, the vat, containing the pulp, is situated, having a lip, or low side, at which the pulp runs over in a continued stream upon the cloth, and is, by its motion, carried forwards; the cloth is contrived to have a continual shaking motion sideways, which tends with the draining through of the water to coagulate the pulp into a sheet of paper; this is taken off from the wire, at the other end, in a continued sheet, between a pair of rollers, like those of a flatting-mill; each of these has an endless felt passing round it, and the paper is introduced to receive its pressure between the felts, so that it is delivered from the machine in a continued dry and firm sheet. A reel, turned by the machine, receives the paper, and winds it up as it comes off the cloth; and when a sufficient quantity is wound on it, it is cut off by a knife, which, by cutting through the folds, divides the paper into separate sheets, which are ready for the operation of the second press. The machines are constructed with the cloth so wide, that the continual sheet is cut up into two, and sometimes three, in width, by which means it produces an immense number of sheets in a short time; but the greatest advantage is in making very large sheets, which it will do to almost any extent in length, and as much as two yards in width. This machine is only adapted for making wove paper, but a patent has lately been taken out for carrying this invention further, and making the paper with lines in it, which is done in separate moulds, similar to those at present used, but worked by machinery.

Mr. Bramah, Mr. Dickenson, and Mr. Cobb, have, at different periods, taken out patents for paper-machines; but it has not come to our knowledge whether they have carried their inventions into practice, as Messrs. Fourdrineer's have done.

The great price which rags have acquired of late years, in consequence of the great increase of printing and the paper trade, has induced many ingenious men to turn their attention to discover other materials for making paper. A very large manufactory was established some years ago, in London, for making straw-paper at Mill Bank, by the river-side, but the scheme proved abortive, and the premises were lately disposed of.

In 1802, Mr. Matthias Koop invented the *following* method of making straw-paper, for which he obtained a patent. For each pound of straw, or hay, a pound or a pound and a half of quicklime is to be dissolved in about a gallon or six quarts of river water. The hay, or straw, is to be cut into portions about two inches in length, then boiled in a considerable quantity of water, viz. about two gallons to a pound of materials, for three quarters of an hour. It is then to be macerated in the solution of lime and water for five, six, seven, or more days, taking care to agitate the mass by frequently stirring and turning it over. At the end of this time the lime-water is to be drawn off, and the materials to be washed very clean, then boiled in a large portion of clean river water. This part of the operation is to be repeated; and, for the sake of improving the colour of the paper, one pound of dissolved crystal of soda, or pot-ash, may be used to every thirty-six pounds of straw or hay. When the materials are pressed out of the water, the manufacture of them into paper may be proceeded with by the usual and well-known processes. In some cases, the patentee has thought it advisable to suffer the materials to ferment and heat before they were reduced to a pulp, as was formerly the case with the rags for paper-making. This, however, will always depend upon the warmth of the season.

When thistles are used, they are to be cut down when the bloom begins to fall, to be dried, and reduced into lengths of two inches; and then the same process to be made use of, as has been already described with regard to the straw and hay. See STAINING.

PATTEN-MAKING.

THIS is one of the minor manufactures, when carried on alone, but it is often conducted with some other branches of business. A patten has been defined an under shoe of wood, with an iron ring, worn under the common shoe by women, to keep them from the dirt. Trifling as this article is, yet it requires the aid of several persons to render it complete. The wooden sole, or support, is made chiefly of beech, by persons in London or elsewhere; the iron rings are manufactured at Birmingham and Sheffield; the leathern straps require the aid of the currier or leather-dresser; and, besides these, ribbands or other strings are wanting to fasten those straps tight to the feet. The chief tool for the wood-work is a knife, of peculiar construction, fastened down at one end and moveable on a joint at the other. This seems to be the only description necessary with regard to the common patten. It may, however, be right to say, that His Majesty's letters patent have been granted to two persons for improvements of this article. In the year 1798, Mr. Hornblower obtained an exclusive right for an invention that is thus described:—First, instead of that part of the common pattens now made of wood, to which the rings are rivetted, he substitutes iron, or any other metallic substance, which renders them, he says, much more elegant, lighter, and not so liable to collect the dirt. Secondly, in order to make the pattens as light as possible, he makes them of thin iron plates, or of latten, or iron dipped in tin; and to prevent their bending or giving way, by the weight of the wearer, he applies a piece of iron, or other metallic substance, under the bend of the patten, rivetted at each end, which prevents the patten from bending or getting out of the true form. Thirdly, he causes the ties to be fixed to the iron by rivetting, or otherwise. Fourthly, in some cases, instead of the ties now made, he applies elastic ties, made of any metallic substance, covered with leather, cloth, &c., something in the same way as the ties are usually managed. And, lastly, he fixes to the hinder part of the patten, or otherwise, an elastic string, made of brass wire, covered with leather or cloth, and coming round the hinder part of the foot, by means of which the patten is fixed very firmly on the foot.

In June, 1801, Mr. Josiah Longmore obtained a patent for the manufacture of a patten or clog, which, by the aid of an elastic tongue or spring, made of iron, or any other metallic substance, through a perforated hole in the middle of the block of the patten, presses against the sole of the shoe, thereby keeping it tight against the ties. The foot or block of the patten or clog may be made of iron, wood, cork, or of any other material adapted to the occasion, or of any two or more substances united.

Patten-shoes have been introduced into the veterinary art: it is a horse-shoe so called, under which is soldered a sort of ball of iron, hollow within. It is designed for hip-shot horses, and put upon the sound limb, so that the horse not being able to stand easily upon that foot may be obliged to support himself upon the lame foot, and thus counteract the disposition in the sinews to contract the haunch. Some writers on this subject contend that the patten-shoe is only necessary in old lamenesses where the muscles have been a long while contracted.

In some parts of Lincolnshire, a patten of a different kind has been used, namely, a flat piece of board, adapted by proper ties to each foot of the horse, when he is sent on land too tender to bear the weight of the animal; and from land that would be much injured by the horses in the common way, great crops have thus been obtained. By cultivation, the same soil has, in a few years, become sufficiently firm to carry the horses without this precaution.

PIN MAKING.

A Pin, though an apparently insignificant instrument, is an important article in commerce. The art of making pins, of brass wire, was not known in England before the year 1543: prior to that period they were made of bone, ivory, or box. In the year 1543, by statute 34 and 35 of Henry VIII., cap. vi., it was enacted, "that no person shall put to sale any pins, but only such as shall be double-headed, and have the heads soldered fast to the shank of the pins, well smoothed; the shank well shapen, the points well and round filed, cauted, and sharpened." From the above extract it should appear that the art of pin-making is but of late invention, probably introduced from France, and that our manufactories since that period have been wonderfully improved.

The pin manufactory was introduced into Gloucester, in 1626, by John Tilsby. There are now, in Gloucester, nine distinct pin manufactories, which employ, together, at least, 1,500 persons. The pins sent annually to the metropolis amount to the value of £20,000: but the chief demand is from Spain and America.

Though pins are of apparently simple construction, their manufacture, however, is not a little curious and complex. We have traced, says a traveller, with much pleasure the whole process in the manufactories at Gloucester, and observed, that the article, small as it is, passes through several hands from its first state of rough wire to its being stuck in paper for sale. The following may suffice for a general sketch of the method.

When the brass wire, of which the pins are formed, is first received at the manufactory, it is generally too thick for the purpose of being cut into pins. The first operation, therefore, is that of winding it off from one wheel to another, with great velocity, and causing it to pass between the two through a circle, in a piece of iron of smaller diameter; the wire being thus reduced to its proper dimensions, is straightened by drawing it between iron pins, fixed in a board, in a zig-zag manner, but so as to leave a straight line between them; afterwards, it is cut into lengths of three or four yards, and then into smaller ones, every length being sufficient to make six pins: each end of these is ground to a point, which is done by boys, each of whom sits with two small grinding-stones before him, turned by a wheel. Taking up a number in his hands he applies the ends to the coarsest of the two stones, being careful, at the same time, to keep each piece moving round between his fingers, so that the points may not become flat: he next gives them a smoother and sharper point, by applying them to the other stone. By this means, a lad of fourteen years old is enabled to point sixteen thousand pins in an hour. When the wire is thus pointed, a pin is taken off from each end, and this is repeated. The next operation is that of forming the heads, or, as it is termed, head-spinning, which is done by means of a sort of spinning-wheel; one piece of wire being thus, with great rapidity, wound round another, and the interior one being drawn out, leaves a hollow tube between the circumvolutions; it is then cut with shears, every two circumvolutions or turns of the wire forming one head: these are softened by throwing them into iron pans, and placing them in a furnace till they are red hot. As soon as they are cold they are distributed to children, who sit with anvils and hammers before them, which they work with their feet, by means of a lathe, and, taking up one of the lengths, they thrust the blunt ends into a quantity of heads which lie before them, and catching one at the extremity, they apply it immediately to the anvil and hammer, and, by a motion or two of the foot, the pointed end and the head are fixed together in much less time than it can be described, and with a dexterity only to be acquired by practice.

We may notice a new invention for heading pins by Mr. William Bundy, of Camden Town, to whom was granted His Majesty's letters patent, in September 1809. This operation is performed by means of a frame or stock made of metal, in which are fitted a pair of steel dies, in the manner of those generally used in the manufacture of screws, held together by cylinders; the dimensions may be various, according to the quality of the work, but the dies most generally in use are about two inches long, and one inch wide. In the prominent parts and on that side of each of the two dies which comes in contact when in use are made corresponding grooves, which when pressed together form holes, each to be the diameter of the shaft intended to have the head fixed on; these holes may be made tapering upwards, or contracted at that part close under the head, where half a hemisphere, whose diameter being that of the size of the head required, is to be worked out. Viewing the dies thus worked, and in a particular kind of frame, which is the position in which they are placed while introducing the pointed shafts, each having a head loosely put on, the upper die being at liberty in the frame,

frame, the pressure of its weight will be found sufficient to hold the number of shafts, with their heads in their respective places, while they are pushed forwards with a straight motion, till the quantity of the heads prevents the shafts from going any farther. In this state it is necessary to turn a lever, to which is fixed a screw for the purpose of forcing the dies together, which will hold the shafts firm enough to receive a stroke from a press on the top piece to secure and form complete the whole number of heads in the dies. The hemispheres are to be finished according to fancy, as respects the ornament or figure of moulding intended for the top of the head by sinking them accordingly. The patentee says, "I leave a point in the centre of those cavities in the top piece, which serves when forced into the top of the shaft to widen it there, and form a rivet, and thereby secure the head firm from coming off the top of the shaft; and the dies being hard screwed together with the lever, there will be a collar formed by that pressure on the shaft under the head sufficient to prevent the liability of the head being by any ordinary means forced down the shaft. Having described the working parts and explained the process by the drawings, Mr. Bundy adds, that placing the whole in a fly press, one stroke therewith on the top piece will be found sufficient to complete the whole number of heads in the dies. Hitherto it has been the practice to strike the head several times, " but my method," says Mr. B., " of effectually and securely fastening the heads on the shafts, and leaving the heads of a superior form, is by placing the shafts in a perpendicular direction, and striking the heads and shafts on their tops, which I call superior heads, and which method I claim as my invention. To succeed in the completest manner in forming these superior heads, it will be necessary that the dimensions of the heads before they are fixed to the shafts, should be particularly attended to. If they are to be of nearly a spherical figure, they should be prepared of a greater depth of axis than the diameter; that the diameter may be small enough to go freely into the hemispheres in the dies and top piece which are to receive them; for this purpose head wire may be made flat, either by drawing or rolling to a size, so that when spun, one or more rounds will be sufficient for a head. I recommend head wire of a smaller size than ordinary without flatting, so that when spun and cut three rounds, it shall contain the quantity of metal required for the size of the intended head." When the heads have been fixed on the shafts by the fly press, the screw is then to be turned back by a lever, and taking hold of the milled head, which is on the head of the small shaft, and which goes through the screw, and is fixed to the top dies by being screwed hard in the die: it may be drawn back to separate the dies sufficiently wide for the superior headed pins which they contain, to fall through into some place prepared to receive them.

The pin is now finished as to its form, but still it is brass; it is therefore thrown into a copper containing a solution of tin and leys of wine, where it remains some time, but when taken out it assumes a white but very dull appearance: to give it a polish, it is put into a tub containing a quantity of bran, which is set in motion by turning a shaft that runs through its centre; and thus by means of friction it becomes perfectly bright. The pin being complete, it only remains to separate it from the bran, which is performed by a sort of winnowing, the bran flying off and leaving the pin behind.

On the Continent the mode of tinning brass pins is rather different from that just described. A vessel is filled by layers with plates of tin and brass pins, a tin plate being at the bottom and another at the top. The vessel is then filled with water, adding some cream of tartar, by the acid of which the tin is dissolved. After about five hours boiling the pins are found to be uniformly tinned.

The pins of this country are those most in repute, as well in the pointing as the whitening, because our pin-makers in pointing use two steel mills, the first of which forms the point, and the latter takes off the irregularities, and renders it smooth, and as it were polished. In whitening they make use of the best block-tin granulated, whereas in some places they are said to have recourse to a mixture of tin, lead, and quicksilver; which not only whitens worse than tin, but is also dangerous on account of the ill quality of the mixture, which renders a puncture with a pin thus whitened somewhat difficult to be cured.

Pins are sometimes made of iron-wire, rendered black by a varnish of linseed-oil with lamp-black: these are designed for the dress of persons in mourning.

PIPE-MAKING.

Pipes are of various sorts, as tobacco-pipes, once much in use by persons of all conditions, but now the practice of smoking tobacco is very generally laid aside by persons in the middle class of life, and almost wholly by those who move in the higher circles. Still the demand for them is considerable, and there are many manufacturers of them in the vicinity of London. It seems, however, to be one of the very lowest among our manufactures, and those employed in it seem never to rise to a state of competence. There are pipes likewise which answer the purpose of canals or conduits for the conveyance of water and other liquids. These are made of wood, of lead, of iron, of copper, of pottery ware, and of stone. We shall give a sketch of the manufacture of these.

Tobacco-pipes are too well known to need a minute description: they consist of a long tube from 12 to 15 or 18 inches in length, made of a peculiar kind of clay, having at one end a little bowl for the reception of tobacco, the smoke of which when lighted is drawn by the mouth through the other end. Tobacco-pipes are made of various shapes and fashions: some are long, others are short; some are very plain, and can in these times be sold to the publicans at the rate of four or five a penny; others are handsomely wrought and varnished of different colours, and are sold as high as from eight to twelve shillings per gross. The Turks who are famed for smoking, make use of pipes three or four feet long made of rushes or of wood, bored at the end whereon they fix a kind of pot of baked earth, which serves as a bowl and which they take off after smoking. The clay of which tobacco-pipes are made is perfectly white, and is distinguished from other kinds of clay by its great adhesion to the tongue, which is well known to be considerable when baked, in consequence of its affinity to water. In a raw state this property is perceptible in a slight degree. The pipe-clay is found at the island of Purbeck in Dorsetshire, and at Teignmouth, in Devonshire, in large lumps which are purified by dissolving in water in large pits; the solution being well stirred up is poured off into another, where it subsides and deposits the clay; the water becoming clear is let off, and the clay at the bottom is left sufficiently dry for use; by this means the smallest stones or particles of foreign matter are left at the bottom of the first pit; the clay thus prepared is spread on a board and beaten with an iron bar to temper and mix it; then it is divided into pieces of the proper size to form a tobacco-pipe; each of these pieces is rolled under the hand into a long roll with a bulb at one end to form the bowl, and in this state they are laid up in parcels for a day or two, until they become sufficiently dry for pressing, which is the next process, and is conducted in the following manner: the roll of clay has a small wire thrust nearly through its whole length to form the tube, and is put in between two iron moulds, each of which has imprinted in it the figure of one half of a pipe, and therefore when put together the cavity between them is the figure of a whole pipe. They are put together by pins which enter holes in the opposite half. The moulds with the clay in them are now put into a press which consists of an iron frame formed of two plates, one of which is fixed down to the bench, and the other pressed towards it by a screw turned round by a handle. The moulds are put in between the two plates, and the screw being turned round presses them together, imprinting the figure of a pipe on the clay included between them. The lever is next depressed, and the stopper entering the mould forms the bowl of the pipe, and the wire which is still in the pipe is thrust backwards and forwards to carry the tube completely into the bowl. The press is now opened by turning back the screw, and the mould taken out. A knife is next thrust into a cleft of the mould left for the purpose, to cut the end of the bowl smooth and flat: the wire is carefully withdrawn, and the pipe taken out of the mould. The pipes when so far completed are laid by two or three days properly arranged for the air to have access to them in all their parts, till they become stiff, when they are dressed with scrapers to take off the impression of the joints of the moulds: they are afterwards smoothed and polished with a piece of hard wood. The next process is baking or burning, and this is performed in a furnace of peculiar construction. It is built within a cylinder of brick-work, having a dome at top, and a chimney rising from it to a considerable height to promote the draught. Within this is a lining of fire-brick-work having a fire-place at the bottom of it. The pot which contains the pipes is formed of broken pieces of pipes and cemented together by fresh clay and hardened by burning: it has a number of vertical flues surrounding it, conducting the flame from the fire-grate up to the dome, and through a hole in the dome into the chimney. Within the pot several projecting rings are made, and upon these the bowls of the pipes are supported, the ends resting upon circular pieces of pottery which stand on small loose pillars rising up in the centre. By this sort of arrangement a small pot or crucible can be made to contain fifty gross of pipes without the risk of damaging any of them. The

pipes

pipes are put into the pot at one side when the crucible is open, but when filled this orifice is made up with broken pipes and fresh clay. At first, the fire is but gentle, and it is increased by degrees to the proper temperature, and so continued for seven or eight hours, when it is damped and suffered to cool gradually, and when cold the pipes are taken out ready for sale. We have been aided in the above description, by attending at the manufactory for pipes of Mr. W. Andrews, Highgate, and observing the several processes from the clay in lumps to the perfect pipe.

Wooden pipes are trees bored with large iron augers of different sizes, beginning with the less and proceeding on to those that are larger; the first being pointed, the rest are formed like spoons, increasing in diameter from one to six or eight inches; they are fitted into the extremities of each other. Wooden pipes, if small, are frequently bored by mere manual labour, but where they are large and made of hard wood, the use of horses or of the steam engine is required. On the large scale the following will serve as a description: the piece of timber, or perhaps the tree itself, when a little shaped on the outside by the axe, intended to form a pipe, is placed on a frame and held down firmly upon it by means of iron chains going over it and round two windlasses; it is at the same time wedged up to prevent its rolling sideways: if the piece is tolerably straight this will answer every purpose, otherwise it must be fixed firm by wedges, iron hooks, &c., similar to those used by sawyers, drove into the carriage at one end and into the tree at the other. The frame and tree being bound together run upon small wheels traversing two long beams, or as they are usually called ground-sills, placed on each side of a pit dug to receive the chips made by the borers. At one end they are connected by a cross beam bolted upon them; this supports the bearing for a shaft, the extremity of which beyond the bearing is perforated at the end of a square hole, to receive the end of the borer. The timber and carriage are made to advance towards the borer by means of ropes: one rope being made to wind up, while the other gives out and draws the carriage and piece of timber backwards and forwards according as the wheel is turned. The weight of the borer is supported by a wheel turning between uprights fixed on a block, the end of which rests upon the ground-sills. It is moved forwards by two iron bars pinned to the front cross-bar of the carriage. The distance between the wheel and the carriage may be varied, by altering the iron bar and pins so as to bring the wheel always as near as convenient to the end of the tree. The shaft, as we have already hinted, may be turned by any first mover, as wind, water, horses, or steam, as is most convenient, and a man or boy regulates the wheel. When the borer is put in motion by turning the wheel, he draws the tree up to the borer that pierces it; when a few inches are bored he draws the tree back by reversing the motion of the wheel, in order that the borer may throw out its chips; he then returns the tree, and continues the process till the work is finished. The borer in this case, be its size what it will, is of the same shape as that of a common auger.

Mr. Howel, of Oswestry, some years back, invented an engine for the purpose of boring or hollowing wooden water-pipes, by means of which the process is not only much more expeditious, but causes a considerable saving of timber. By this mode, instead of the common method of boring by augers, or instruments of any other description which perforate the wood by cutting out the inner part of the substance in chips or shavings, a hollow tube or cylinder, made of thin plates of iron, or other metal, about one inch less in diameter than the hole to be bored, is to be made use of. To one end of this tube or cylinder is to be fixed a flanch or ring, of from one quarter of an inch to five-eighths of an inch in breadth; and one part of the circumference of this flanch or ring is to be divided or separated, so that if it be made of steel, an edge or cutter may be formed thereby; or, for the more convenient use of it, a cutter of steel, or other metal, may be screwed, or otherwise connected with the tube and the flanch or ring. The operation of this instrument is, that it will bore out a piece of wood capable of being converted into a pipe or pipes of less dimensions, and that it will do this with the aid of less power, and at less expense and with less waste of wood than by means of the boring instrument now in use.

By another invention, pipes have been made of separate pieces or staves, instead of boring a solid tree or timber. In this case, the end of one piece of pipe is tapered off to fit into the next piece, and the different parts are connected by dove-tailing, rabbeting, or by means of screws, or by any other method of joining the surfaces of wood together. The outer and inner surfaces may be painted, varnished, or covered over with pitch, tar, or any kind of cement that can be made to adhere to wood.

The method of making leaden pipes consists in casting the lead upon a smooth steel mandril, placed in a mould also of metal, to form the outside. These pieces are about eighteen inches long. They are afterwards joined together by a process called *lining*.

A very great improvement has been made in the manufacture of leaden pipes, by drawing them in a manner similar to wire. The lead to form the pipe is cast upon a mandril of the diameter of the inside of the pipe, but of such a thickness as to equal the whole pipe in weight; it is then fastened upon one end of a cylindric steel mandril, and the lead is pulled through different sized holes till the pipe is of sufficient length and thickness. These pipes can be drawn to the length of eight or ten feet. The power required, however, is very great, which is one objection to the method. They are also liable to flaws, for, if the casting happen to be imperfect, the imperfection is much increased and extended by the process of drawing.

This manufacture has been much improved by passing the lead upon the mandril through grooved rollers of

of different sizes, following each other in succession. The power required is much less than that required for drawing; and the pipes are said to be superior in other respects. For this method of manufacturing leaden pipes, Mr. John Wilkinson obtained His Majesty's letters patent about twenty years ago.

For the manufacturing of iron pipes, we refer to the article FOUNDING, it being a considerable branch of the iron-founder's business. Copper and tin are rarely used for pipe-making; the former being too expensive, and the latter not sufficiently durable: when, however, recourse is had to these metals, they are bent round mandrils, or other proper instruments, and the edges soldered together.

Of late years we have seen pipes, made of pottery, brought much into use. In the neighbourhood of London, and other large towns, where it is difficult to preserve any thing from the hands of the pilferer, they are excellent substitutes for lead, as they afford no temptation to theft, and if the passage be always kept clear, so that the water will not be stopped in its course, they must be durable. Mr. Bell, of Birmingham, in 1808, obtained, by His Majesty's letters patent, the exclusive privilege of manufacturing them. We shall transcribe his own account attached to the specification:—

"It has been found, by long experience, that pumps or pipes for conducting water from water-works which have been made of wood, or iron, lead, or any other metallic substances, have been justly objected to, for the various following reasons:

"First. Pumps or pipes which are made of wood are liable to constant decay, and in a short time to become rotten: and it is invariably the case that in their rotten or decayed parts they generate insects and vast numbers of noxious animalculæ, which may always be discovered in water which passes through wood pipes or pumps which have been some time in use; and Dr. Buchan observes, that 'waters become putrid by the corruption of animal and vegetable bodies with which they abound.' Water, which is conducted through pumps or pipes which are made of iron, lead, copper, or most other metallic bodies, becomes impregnated with the corrosive qualities of the metals which renders it unwholesome and poisonous, and, of course, unfit for cooking or washing linen, and many other domestic uses. The nature of my improvement is, therefore, to remove the aforesaid objections, which I completely perform by making tubes of porcelain pottery, and various compositions which are vitrifiable, and are not liable to corrosion or decay. These tubes are formed in such a way at the ends as to fit one within the other, which I connect or unite together by cement, so as to make them water or air tight. And by the addition of any number of these tubes, connected as aforesaid, I form one complete tube or pipe to any extent which may be required. I prefer the method of enclosing them in cast-iron pipes or cases, which are to be made in various ways and forms; which pipes or cases serve as defenders of these porcelain or pottery tubes, to prevent breaking or bursting. Cases or pipes may be made of wood, and various other substances, for enclosing these porcelain or pottery tubes or pipes; but, for the sake of compactness, strength, and durability, I recommend cast-iron cases, boxes, or pipes. There are compound metals which are less corrosive than the real metals as aforesaid, of which tubes may be made, and if enclosed in the manner before described would be useful in conducting water and various liquids, either hot or cold, for particular purposes; as also thin tubes, made of wood, which may be prepared for durability by boiling it, or burning or charring it, which has the effect of preventing its breeding or harbouring insects, &c. These, in addition to my porcelain or pottery tubes enclosed, I claim the originality of."

The Manchester Water-Works Company employ stone pipes for the conveyance of their water, and the stone which they have found most suitable to their purpose comes from a quarry at Fox-Hill, in the parish of Gorting-Power, Gloucestershire, which is very like the Portland-stone; but the latter is the more dense or specifically heavy, in the proportion of 17 to 16; that is, the Fox-hill stone requires seventeen cubical feet to the ton, but sixteen feet only of the Portland-stone go to the ton. The following method is used in boring the stone for pipes: the first mover is a steam-engine of a power adapted to the work, giving a rotatory motion to a shaft placed horizontally, and running from one end of the works to the other. The works are divided into compartments, each of which serves for the boring of four pipes at the same time; by means of what is known to mechanics, by the name of the bevel-geer, motion is communicated from the main horizontal shaft to a vertical arbor, at the top of which is a wheel. The rotatory motion of this wheel, by means of a crank bar, gives a reciprocating motion to the larger wheel, and this latter motion is such as to give rather more than a complete rotation to each of four smaller wheels placed opposite; with respect to the larger wheel, the mutual connexion between them and it, being by means of teeth or cogs. Thus the small wheels go through somewhat more than a complete rotation in one direction, and then rather more than a complete rotation in the opposite direction, and so on alternately. On the vertical shafts, beneath the smaller wheels, are placed iron tubes, which are suffered to act by their own weights upon the stones to be bored, and by means of their rotation to bore those stones by attrition. The stones are cut into lengths of six or eight feet, and bored into pipes of various diameters. When the pipes are of fourteen inches diameter, the thickness of stone allowed is about five inches. The tubes, by which the boring is effected, are, of course, fourteen inches in diameter, and weigh about one hundred and a half. They are made of thin plate iron, except their circular rim or sole at the bottom, which is about half an inch thick. As the attrition wears away the stones on which the soles of the tubes rest, they sink lower and lower; the

the whole is kept moist by a sort of semi-fluid mixture of sand and water, which runs down from the small wheels at the top of the tubes, and, after sinking to the bottom of those tubes, carries up with it the particles of the stone taken off during the process of boring.

PLANING.

Although this art is strictly connected with Carpentry, Joinery, and Cabinet-making, yet we make a distinct article of it, in order to introduce an account of Mr. Bramah's patent machinery, which we believe to be not only interesting and curious, but adapted to various purposes of utility.

A plane is an edged tool for paring and shaving of wood smooth. It consists of a block of wood, very smooth at bottom, as a stock or shaft, in the middle of which is an aperture, and through this passes a steel edge, or chisel, placed obliquely, which, being sharp, takes off the inequalities of the wood over which it is slid along. Planes have various names according to their forms, sizes, and uses. Thus, *Fig.* 30, *Plate* I, Carpentry, represents the *fore*-plane, or *jack*-plane, which is very long, and is usually that which is first used: the steel or chisel part is composed of two pieces shewn in *Fig.* 32 and 33, and in this plane they are not ground quite straight, but are left a little convex. They are called the top and bottom irons; the top iron having a screw in it, by which it is fastened to the other after the edges are sharpened. The use of the jack-plane is to take off the greater irregularities of the stuff, and to prepare it for the smoothing-plane.

The *smoothing-plane*, *Fig.* 34, is short and small; its chisel being finer, and its use is to take off the irregularities left by the jack-plane, and prepare the wood for the *jointer*, or trying-plane, which is the longest of them all: its edge is very fine, and does not stand out above an hair's breadth; it is chiefly used for shooting the edge of a board perfectly straight for joining tables, &c.

The *strike-block*, is like the jointer, but shorter; its use is to shoot short joints.

The *rabbet-plane*, which is used in cutting the upper edge of a board, straight or square, down into the stuff, so that the edge of another, cut after the same manner, may join in with it, on the square; it is also used in striking facias on mouldings. The chisel of this plane is as broad as the stock, that the angle may be cut straight, and it delivers its shavings at the sides, and not at the top, like the others.

The *plough*, *Fig.* 29, is a narrow rabbet-plane, with the addition of two staves, on which are shoulders. Its use is to plough a narrow square groove on the edge of a board.

The *moulding*-plane, *Fig.* 35, is of various kinds, accommodated to the various forms and profiles of the moulding; as, the rounding-plane, the hollow-plane, the ogee, the snipes-bill, &c., which are all of different sizes, from half an inch to an inch and a half in width.

Fig. 35, represents a quirk-ogee plane.

There are many other kinds of planes, but we shall now give an account of Mr. Bramah's invention, chiefly in his own words, for producing straight, smooth, parallel surfaces, and curvilinear surfaces on wood, and other materials, requiring great accuracy, in a more perfect and expeditious manner than can be done by the hand.

The principal parts of my invention are as follows; that is to say, to shorten and reduce manual labour, and the consequent expenses which attend it, by producing the effects stated in my patent by the use of machinery, which may be worked by animal, elementary, or manual force; and which said effects are to produce, straight, true, smooth, and parallel surfaces, in the preparation of all the component parts of work consisting of wood, ivory, horn, stone, metals, or any other sort of materials, or composition usually prepared, and render them true and fit for use, by means of edge-tools of every description. I do not rest the merits of this invention on any novelty in the general principle of the machinery I employ, because the public benefit I propose will rather depend on new effects, produced by a new application of principles already known, and machinery already in use for other purposes, in various branches of British manufacture. This machinery, and the manner of using it, with some improvements in the construction, together with sundry tools and appendages never in use before, are particularly described and explained hereunder.

I mean to use and apply for the purposes above stated, every kind of edge-tool, or cutter, already known, either in their present shape, or with such variations and improvements as the variety of operations I may

may encounter may severally call for. But the tools, instead of being applied by hand, as usual, I fix, as judgment may direct, on frames driven by machinery: some of which frames I move in a rotary direction round an upright shaft; and others having their shaft lying in a horizontal position, like a common lathe for turning wood, &c. In other instances I fix these tools, cutters, &c., on frames which slide in stationed grooves, or otherwise, and like the former they are calculated for connexion with, and to be driven by, machinery, all of which are hereafter further explained and particularized.

The principal points on which the merits of the invention rest are the following:—First, I cause the materials meant to be wrought true and perfect, as above described, to slide into contact with the tool, instead of the tool being carried by the hand over the work, in the usual way.

Secondly, I make the tool, of whatsoever cutting kind it be, to traverse across the work in a square or oblique direction; except in some cases, where it may be necessary to fix the tool or cutter in an immoveable station, and cause the work to fall in contact with it by a motion, confining it so to do, similar to the operations performed on a drawing-bench.

Thirdly, in some cases I use, instead of common saws, axes, planes, chisels, and other such instruments, usually applied by hand; cutters, knives, shaves, planes, and the like, variously, as the nature of the work may render necessary; some in form of bent knives, spoke-shaves, or deep-cutting gouges, similar to those used by turners for cutting off the roughest part. I also apply planes of various shapes and construction, as the work may require, to follow the former in succession, under the same operation; and which latter I call furnishers.

Fourthly, these cutters, knives, &c., I fix on frames of wood, or metal, properly contrived for their reception, and from which they may be easily detached for the purpose of sharpening, and the like—these I call cutter-frames. These cutter-frames I move in cases like those on which the saws are fixed in a saw-ing-mill, and sometimes to reciprocate in a horizontal direction, confined and stationed, by grooves or otherwise, as may be found best calculated to answer the several works intended. In other instances, and which I apprehend will generally have the preference, I fix cutter-frames on a rotary upright shaft, turning on a step, and carrying the frame round in a direction similar to the upper mill-stone; and sometimes I cause the frames to turn on a horizontal shaft, just resembling the mandril of a common turning-lathe, or those machines used for cutting logwood, &c., for the dyers' uses. When these frames are mounted in any of the foregoing directions for cutting; planes, &c., are fixed so as to fall successively in contact with the wood or other materials to be cut, so that the cutter or tool, calculated to take the rough and hilly part, operates the first, and those that follow must be so regulated as to reduce the material down to the line intended for the surface. These cutter-frames must also have the property of being regulated by a screw or otherwise, so as to approach nearer the work, or recede at pleasure, in order that a deeper or shallower cut may be taken at discretion, or that the machine may repeat its action without raising or depressing the materials on which they act. The manner of thus regulating the cutter-frames, when on an upright shaft, is particularly described below. These cutter-frames may be made of any magnitude and dimensions the work requires, only observing to make the diameter of those on the rotary plane so as to exceed twice the width of the materials to be cut, as the said materials must slide so as to pass the shaft on which the cutter-frame revolves, when on the upright principle.

Fifthly, when I use upright shafts, for the purpose of carrying the cutter-frame as above described, I do not mean that the lower end or point of such shafts shall come in contact with, or rest on, the bottom of the step or box in which they stand: neither do I mean that such said shafts shall rest or turn on any stationed unalterable point at rest, but the pivot or lower point of the shaft shall actually rest and turn on a *fluid body*, such as oil, or any other fluid proper for that purpose, a considerable portion of which is always to be kept between the lower point of the shaft and the bottom of the step in which it works. The said shafts may be either raised or depressed at pleasure to any required altitude, by means of a greater or less quantity of the said fluid being confined as aforesaid between the end of the shaft and the bottom of the step. This device I deem of great consequence in the fabrication of all kinds of machinery, where massy and heavy loaded upright shafts are used; and I perform it in the following manner: that is to say: the lower part of the shaft must be turned perfectly smooth and cylindrical, to a height something above the greatest distance or length the shaft will ever be required to be raised or depressed when in use. This part of the shaft I immerse or drop into a hollow cylinder, which fits its circumference near enough to allow freedom of motion, but sufficiently fitted to prevent shake. This cylinder I call the step-cylinder, and which must be of a length nearly equal to that of the cylindrical part of the shaft above-mentioned, so that when the point of the shaft rests on the bottom of the cylinder, the parallel or cylindrical part may be something above the top or upper end of the step-cylinder. In the upper end of this step-cylinder I make a stuffing-box, by means of a double cupped leather, or other materials, surrounding the cylindrical part of the shaft, in such a way as will cause the junction, when the shaft is passed through it, to remain water-tight under any pressure that may be felt from the efforts of the fluid retained as before mentioned, to make its escape upwards through this part, which I have called the stuffing-box, when the shaft, with all its load, is passed through it, and immersed in the cylinder below. When this is done, the injecting-pipe of a small forcing-pump, similar to those I use in my patent press,

press, must form a junction with the step-cylinder in some part below the stuffing-box; then the pump being worked, the oil, or other fluid injected by it, will, by pressing in all directions, cause the shaft to be raised from its rest, on the bottom of the cylinder, and to be slided up through the stuffing-box just the same as the piston of my patent press; and by this means the shaft, with all its encumbrance, and whatever may be its weight, may be raised to any given point at pleasure, and at the same time it will be left resting on the fluid under it, whatever the quantity or thickness of such fluid may be between its point and the bottom of the step-cylinder. By this means the shaft, with all its incumbent load, as aforesaid, should it even amount to hundreds or thousands of tons, can be easily raised and depressed to any required point at pleasure, by the alternate injection or discharge of the fluid used, exactly the same as performed by my patent press as aforesaid; and at the same time all friction will be avoided, except that of the stuffing-box, which will be comparatively trifling to that which would result from the resting of such a shaft on the bottom of the step, in the usual way. Thus will be gained the properties above stated; and in addition thereto, I think it may be inferred, that, provided the stuffing-box is kept perfectly fluid tight, such a shaft, thus buoyed up by and turning in a proper fluid, may continue working for years, or perhaps hundreds of years, without a fresh supply of oil, or whatever other fluid substance is found the most proper to apply.

Sixthly, the material that is to be cut and made true must be firmly fixed on a platform, or frame, made to slide with perfect truth, either on wheels or in grooves, &c., similar to those frames in a saw-mill on which the timber is carried to the saws. These frames must be moved in a steady progressive manner, as the cutter-frame turns round either by the same power which moves the latter, or otherwise, as may be found to answer best in practice. This motion also must be under the power of a regulator: so that the motion of the sliding frame may be properly adjusted according to the nature of the work. The motion of the cutter-frames must also be under the control of a regulator; so that the velocity of the tool in passing over the work may be made quicker or slower, as such work may respectively require, to cause the cutter to act properly, and to the best advantage.

Seventhly, I regulate the motions of both these parts of the apparatus, as aforementioned, by means of a new invention, which I call a universal regulator of velocity, and which is composed as follows; viz. I take any number of cog-wheels, of different diameters, with teeth that will exactly fit each other through the whole, suppose ten, or any other number, but for example, say ten, the smallest of which shall not exceed one inch in diameter, and the largest suppose ten inches in diameter, and all the rest to mount by regular gradations in their diameters from one to ten. I fix these ten wheels fast and immoveable, on an axis perfectly true, so as to form a cone of wheels. I then take ten other wheels, exactly the same in all respects as the former, and fix them on another axis, also perfectly true, and the wheels in conical gradation also; but these latter wheels I do not fix fast on their axis, like the former, but leave them all loose so as to turn upon the said axis, contrary to the former which are fixed. All these latter wheels I have the power of locking by a pin, or otherwise, so that I can at discretion lock or set fast any single wheel at pleasure. I then place the two axes parallel to each other, with the wheels which form the two cones, as above described, in reverse position, so that the large wheel at the one end of the cone may lock its teeth into the smallest one in the cone opposite, and likewise *vice versa*. Then suppose the axis on which the wheels are permanently fixed to be turned about, all the wheels on the other axis will be carried round with an equal velocity with the former, but their axis will not move. Then lock the largest wheel on the loose axis, and by turning about the fastened axis as before, it must make ten revolutions, while the opposite performs but one: then by unlocking the largest wheel and locking the smallest one at the contrary end of the cone in its stead, and turning as before, the fastened axis will then turn the opposite ten times while itself only revolves once. Thus the axes, or shafts, of these cones, or conical combination of wheels, may turn each other reciprocally, as one to ten, and as ten to one; which collectively produces a change in velocity under a uniform action of the *primum mobile*, as ten to a hundred: for when the small wheel on the loose axis is locked, and the fast one makes ten revolutions, the former will make one hundred. And by adding to the number of those wheels and extending the cones, which may be done *ad infinitum*, velocity may be likewise infinitely varied by this simple contrivance—A may turn B with a speed equal to thousands or millions of times its own motion; and by changing a pin and locking a different wheel, as above described, B will turn A in the same proportion, and their power will be transferred to each, in proportion as their velocities, reciprocally. Here is then a universal regulator at once for both power and velocity. In some instances I produce a like effect by the same necessary number of wheels, made to correspond in conical order, but instead of being all constantly mounted on the axes or shafts, as above described, they will reciprocally be changed from one axis to the other in single pairs, match according to the speed or power wanted, just as in the former instance. This method will have in all respects the same effect, but not so convenient as when the wheels are all fixed, &c.

Eighthly, when spherical surfaces are to be produced perfectly true, and equidistant from their centres in all directions, I use a tool, or cutter, of a proper shape, according to the nature of the materials to be cut. This tool must be fixed on a cutter-frame, fastened to the rest of any common lathe, so as to present its

its point exactly to a line drawn through the centre of the mandrel of the lathe horizontally, and the said frame on which the cutter is fixed must have the capacity of drawing out, at pleasure, to any required distance, to accommodate the diameter of the sphere to be cut or turned true. This cutter-frame must be likewise made to turn upon a centre or pin, very firm, and steadily fixed on the rest above-mentioned, so as to enable the cutter to be turned by its frame round a centre exactly perpendicular to the centre of the lathe or line before-mentioned, by which the altitude of the tool's point is to be regulated; when this is done, and the wood or other materials fixed on the lathe in the usual way, the cutter-frame must be drawn nearer, or farther distant from the centre on which it turns, to accommodate the diameter, just the same as the common rest. If the materials be rough, and require to be reduced to a spherical form by gradations, the work may be repeatedly gone over by the cutter, before it reaches the diameter proposed. By this simple apparatus the difficulty of turning perfect spheres is overcome; as it must be obvious to any person of the most ordinary capacity in mechanics, that while the work is turning in the lathe in a vertical direction, and the tool or cutter is by the hand or otherwise, turned, at the same time, in a perfectly horizontal direction, round a centre, opposite to the actual centre of the sphere, the point of the tool or cutter must, of necessity, generate or turn a perfect sphere, true in all directions, without the smallest attention or assistance from the use of the instrument. I mention here the application of the cutter-frame to a common lathe, conceiving it will, by such an explanation, be more familiarly understood without a drawing; but, by this method, spheres of any practical magnitude may be cut with perfect ease and certainty.

Ninthly, when concave surfaces are to be produced perfectly true, smooth, and equidistant from their respective spherical centres, the work is fixed on a machine the same in all respects as the common turning lathe, as in the instance last referred to; I then fix a tool or cutter on a centre, exactly in a line, both perpendicular to, and on a level with the exact centre of the shaft or mandrel on which the work revolves; and which cutter or tool projects to the required radial distance with its point, so that when the work goes round by the revolution of the lathe, the tool or cutter at the same time revolving round its centre, a spherical concave will be generated and produced by the flection of its point, as in the instance of the convex sphere.

Tenthly, I convert solid wood, or other materials, into a thin concave shell, similar to a dish. I cut them alternately out of each other, beginning at the smallest, by means of another tool or cutter, likewise moving on a stationed centre, as before, exactly on a level with, and perpendicularly true with the centre of the mandrel or shaft of the machine on which the work is fixed. This tool, or cutter, is made at its exterior point, or cutting end, of such a shape as best suits the nature of the work; and its shank, or stem, is bent to the exact circle the concave is meant to be: it is then fixed on an arm or frame calculated to receive others of different circles, according to the work; in fact, the same frame may be used which is above described to hold the tool for cutting spheres, either of the concave or convex kind. The tool must be fixed on this frame or arm, as above-mentioned, at such a radial distance from the centre on which the frame or arm turns, so as to form a quadrant with one leg, turning on its centre, and the tool forming the periphery with its cutting point projecting to the line of the deficient leg. Before this tool begins its action, a common rest must be applied close to the face of the work, in order to support the tool when it begins its cut; and on which rest the tool will slide till its point proceeds under the control of the centre on which its frame is fixed, until it reaches the horizontal line of the lathe's centre, when the part cut off, or the inner dish, will fall from the stock, and leave the rest for the operation of another tool, of a larger circle. Thus the operation may be repeated till the whole lump is converted according to the intentions of the owner.

This is one of the patent inventions that has been brought into use, and is found of very great importance at Woolwich, where it has been long at work, and by which we have been told thousands of pounds are annually saved, as well by the velocity of the work performed, as by enabling the workmen to use up timber that from its knotty substance could not be wrought by the hand.

PLASTERING.

THE plasterer occupies a very considerable space as a mechanic in every department of architecture. To him is intrusted the finishing of the sides and ceilings of the interior of buildings, and, also, the stuccoing in all the various manners on their exterior. The decorative part of architecture owes a considerable part of its effect to the plasterer, as he supplies the facilities of producing it.

Plastering

Plastering, in this article, will be divided, and placed under its several heads, and will include plastering on laths in its several ways; also rendering on brick and stone; and, finally, the finishing to all the several kinds of work of this description. Also, modelling and casting the several mouldings, both ornamental and plain; stuccoing and other outside compositions which are applied upon the exterior of buildings, and the making and polishing the scagliuola, so much the taste now for columns and their antæ.

Lime forms an extensive part in all the operations of this trade; its nature and composition are too well known to be much dwelt upon in this place; chemically considered, its specific gravity is 2,3, and, when *pure*, it is soluble in 300 parts of water. It is reduced to the state known as *quick-lime*, by being deprived of its fixed air, or carbonic acid and water by means of heat generated from fuel in a kiln prepared for the purpose. Limestone, or chalk, intended to be thus reduced, is broken into convenient pieces, and piled with coal or wood, stratum, super stratum, in kilns, where it is kept for a considerable time in a *white* heat, by this means the carbonic acid and water are driven off, and quick-lime is the product. It is vended at the wharfs in bags, and varies in its price from thirteen shillings to fifteen shillings per hundred. Most of the lime made use of in London is prepared from chalk, and the greater proportion comes from Purfleet, in Kent: but, for stuccoing and other work, in which strength and durability are required, the lime made at Dorking, in Surrey, is preferred.

The composition, known as plaster of Paris, is that on which the plasterer is very much dependent for producing whatever is good in his business: by it alone he is enabled to give the form and finish to all the better parts of plastering, with it he makes all his ornaments and cornices, besides mixing it in his lime to fill up the concluding coat to the walls and ceilings of rooms. The stone from which it is obtained is known in the Arts by several names, as sulphat of lime, selenite, gypsum, &c. &c., but it is commonly called plaster of Paris, from the circumstance, perhaps, of the immense quantities which are extracted from a mountain in the environs of Paris, called Mont-martre. The stone from this place is, in its appearance, similar to common free-stone, excepting its being surrounded and full of small specular crystals. The French break it into fragments of about the size of an egg, and then burn it in kilns with billets of wood: till they perceive the crystals have lost their brilliancy, it is afterwards ground with stones to different degrees of fineness, and is then considered fit for use. This kind of specular gypsum is affirmed by some travellers to be employed in Russia, where it abounds, as a substitute for glass in windows. According to chemists its specific gravity is from 1.872 to 2.311, it requiring 500 parts of cold water and 450 of hot, to dissolve it; when calcined it decrepitates, becomes very friable and white, and heats a little with water, with which it forms a solid mass. In the process of burning or calcination it loses its water of crystalization, which, according to Fourcroy, is 22 per cent.

The plaster made use of in London is prepared from a sulphat of lime dug in Derbyshire, and is called *alabaster*. It is said eight hundred tons are annually raised there. It is brought to London in a crude state, where it is calcined, and ground in a mill for use, and vended in brown paper bags, each containing about half a peck; the coarser sort is about fourteen-pence per bag, and the finest from eighteen-pence to twenty-pence. The figure-makers use it for all the casts which they prepare of anatomical and other figures, and it is of the first importance not only to the plasterer but to the sculptor, mason, &c.

The working-tools of the Plasterer consist, in the first place, of a *spade* of the common sort, a two or three pronged rake, which he uses for the purpose of mixing his mortar and hair together. His trowels are of two sorts, and of one of which there are in use three or four sizes. The first sort is called the laying and smoothing tool; its figure consists in a flat piece of hardened iron, very thin, of about ten inches in length and two inches and a half in width, ground to a semicircular shape at one end, while the other is left square; on the back of the plate, and nearest to the square end, is rivetted a piece of small rod iron having two legs, one of which is fixed to the plate, and to the other a round wooden handle is adapted; with this tool all the first coats of plastering are put on the work, and it is also used in *setting*, as it is called, or putting on the final coat of plastering.

The trowels of the plasterer are made more neatly than the tools of the same name used by other artificers. The largest size is about seven inches long on the plate, and is of polished steel, two inches and three-quarters at the heel, diverging to an apex or point, to the wide end of which is adapted a handle, commonly of mahogany, with a deep brass ferrule; with this trowel the plasterer gauges, as he terms it, all his fine-stuff and plaster for the purpose of forming cornices, mouldings, &c. The other trowels are made and fitted up in a similar manner, varying gradually in their size from two to three inches long only.

The plasterer has in use also several small tools, called stopping and picking-out tools; they are made of steel, and well polished, and are of different sizes, commonly about seven or eight inches long, about half an inch wide, flattened at both ends, and ground away till they are somewhat rounding. With such tools he models and finishes all the mitres, and returns to the cornices, and fills up and perfects the ornaments at their joinings. The plasterer keeps all his working tools uncommonly clean; they are polished by the hawk-boys daily, and never put away without being wiped and freed of the plaster about them.

The plasterers require many rules and models of wood; these rules, or straight-edges, as they are called, enable them to get their plastering to an upright line, and the models to run plain mouldings, as cornices, &c.

The cements made use of by the plasterer for the interior work, are of two or three sorts. The first of which is called *lime and hair*, or *coarse stuff*, this is prepared in a similar way to common mortar, with the addition of having the hair from the tan-yards mixed in it. The mortar to form lime and hair is previously mixed with the sand, and the hair added afterwards; this the labourers incorporate by the three-pronged rake.

Fine stuff, as it is termed, is *lime only*, slaked with a small portion of water, and afterwards saturated to excess, and put into tubs in a semi-fluid state, where it is allowed to settle and the water to evaporate. A small proportion of hair is sometimes added to the fine stuff.

Stucco for inside walls, called troweled or bastard stucco, is composed of the fine stuff above described, and very fine washed sand, in the proportion of one of the latter to three of the former. With such stucco all walls intended to be painted are finished.

Mortar, called *gauge-stuff* by the plasterer, consists in taking about three-fifths of fine stuff and one of plaster of Paris, and mixing them together with water, in small quantities at a time, to render it more susceptible of fixing or *setting*, as it is called. A cement so gauged, is employed to form all the cornices and mouldings which are run with a mould of wood. The plasterers gauge all their mortars with plaster of Paris when great expedition is required, as they can immediately proceed in their work by so gauging the mortar, as it fixes and sets as soon as laid on.

Plasterers have technical divisions of their work, by which is designated its quality, and from which its value is ascertained.

Lathing consists in nailing up slips of wood on the ceiling and partitions, which are rended from fir, or oak, and are called *three-foots* and *four-foots*, being of these several lengths, and are purchased by the bundle or load. There are three sorts of laths, viz. single laths, lath and half, and double laths. Single laths are the cheapest and thinnest; lath and half is supposed to be one-third thicker than the single lath; and the double laths twice their thickness. The laths most in use in London are made of fir, the wood for which is imported from the Baltic and America, in pieces called staves. All the London timber-merchants are dealers in laths, and there are many places besides, which confine themselves exclusively to this business. The fir laths are generally fastened by *cast-iron nails*, whereas the oaken ones require wrought-iron nails, as no nail of the former kind would be found equal to the perforation of the oak, but would shiver in pieces in the attempt at driving them through it. In lathing ceilings, it is desirable the plasterer should make use of both the usual lengths, and so manage the nailing of them up that the joints are as much broken as possible, which will tend much to strengthen the plastering with which they are to be covered, by giving them a stronger *key* or *tie*. The strongest laths are adapted to the ceilings, and the slightest or single laths to the partitions of buildings.

Laying, as it is called, consists in spreading a *single* coat of lime and hair all over a ceiling or partition, taking care that it is very even in every part, and quite smooth throughout. This is the cheapest manner of plastering.

Pricking-up is a similar method to laying, excepting that it is used as a preliminary to a more perfect kind of work; after the plastering has been put by in this method, it is *crossed* all over with the end of a lath which has the effect of giving a *key* or *tie* to the finishing coats, which are to follow afterwards.

Lathing, laying, and set, mean that the work is to be lathed as before described, and covered with *one* coat of lime and hair, and when this is sufficiently dry, finishing it by covering it over with a thin and smooth coat of lime only, called, by the plasterer, *putty*, or *set*. This coat is spread by the workman with his smoothing trowel; in doing which he is supplied with a large flat hog's hair brush and water. In his right hand he holds his trowel, and in his left the brush: and as he lays on the *set* he draws the brush backwards and forwards over it, and by the assistance of the brush and trowel he is enabled to get the ceiling or wall *tolerably* even for this cheap kind of work.

Lathing, floating, and set, consist as before in respect of the lathing and covering them over by a coat of plastering, excepting only, that for the floated work, a *pricking-up coat* is used; when this coat is sufficiently dry another is put on to receive the set, and which is called the *floating:* this is performed in manner following, viz. the plasterer provides himself with a strong rule, or straight-edge, often from ten to twelve feet in length; two workmen are necessary in this part of the work, as one would be inadequate to the handling of the straight-edge. It is begun by plumbing with a plumb-rule, and trying if the parts to be floated are upright and straight, by which is ascertained where the *filling-out*, as it is called, is wanting. This they do by putting on a trowel-full or two of lime and hair *only*; when they have ascertained these preliminaries, the *screeds*, as they are called, are commenced to be formed.

A *screed* in plastering means a stile formed of lime and hair about seven or eight inches wide, gauged exactly true, by drawing the straight-edge over it till it is so. In floated-work such screeds are made at every three or four feet distance vertically round a room, and are gotten perfectly straight by applying the straight-edge to them to make them so, and when all the screeds are formed the parts between them are filled up with lime and hair, or *stuff*, as it is called, until they are quite flush and even with the face of the screeds. The straight-edge is then worked horizontally upon the screeds, which has the effect of taking off all superfluous stuff which projects above them. In this way is finished the *floating* by adding stuff continually, and applying the rule upon the screeds till it become quite even with them, and *straight* in every part. Ceilings are floated in the same manner, by having screeds formed across

across them, and filling up the intermediate spaces with stuff, and applying the rule as is done for the walls. Plastering is good or bad, in proportion to the care taken in this part of the work, hence the most careful workmen are generally employed about it.

The *set* to the floated work is performed in a similar way to that which has already been described for that to the *laid* plastering; but as floated plastering is employed to the best rooms, it is often performed with more care than is found necessary in that inferior style of work. The set-too for the floated work is frequently prepared by adding to it about one-sixth of plaster of Paris, which fixes it more quickly, and gives it a closer and more compact appearance; and also renders it more firm and better adapted to be whitened or coloured when dry. The dryer the pricking-up coat of plastering is, the better for the floated stucco work; but it is not so exactly for the floating which is to receive the setting-coat, for if the floating be *too* dry before the set is put on, there is a probability of its peeling off, or appearing all over in little cracks or shells, which is particularly to be avoided in doing the ceilings. Good plastering admits of no such defects, and cracks and other disagreeable appearances in ceilings more frequently arise from the weakness of the laths and too much plastering, or, *vice versa*, strong laths and too little plastering, than from the inadequacy of the timbers of the building. Good floated work, executed by a judicious plasterer, is by no means likely to crack, and particularly if the lathing be previously attended to.

Rendering and set, or rendering, floated, and set, embrace a portion of the process employed in both the previous modes, except no lathing is required in this branch of the work. Rendering is to be understood when a wall of brick or stone is required to be plastered over with one coat of lime and hair, and the set designates that it is again to be covered and finished in fine stuff or putty. The method of doing it, is, as has been before described for the setting of the ceilings and partitions for other kind of work. The floated and set is performed on the rendering in the same manner as it is on the partitions and ceilings of the best kind of plastering, and has been explained above.

Troweled-stucco is a very neat kind of work, and is used in dining-rooms, vestibules, stair-cases, &c., or in cases in which the walls are proposed to be finished by painting. This kind of stucco requires to be worked upon a *floated* ground, and the floating should be as dry as possible before the stuccoing is commenced, when the stucco is made as before described; it is *beaten* and tempered with clean water for use. The plasterer about to do it is provided with a small wooden tool, called a *float*, which is merely a piece of half-inch deal, about nine inches long and three inches wide, planed smooth, and a little rounded away on its lower edges; a handle is fitted to the upper side to enable the workman to move it with ease. The stucco is spread upon the ground, which has been prepared to receive it, with the largest size trowel, and made as *even* as possible all over, and when a piece, four or five feet square, has been so spread, the plasterer begins to use the wooden float which he holds in his right hand, and in his left, a brush, and he begins to work by first sprinkling a small part of the stucco with water from a brush, and then applies the float, alternately sprinkling and rubbing the face of the stucco till he reduces it to a perfectly smooth and even surface, and this he continues to do till the whole be finished. The water has the effect of hardening the face of the stucco surprisingly, and when well floated the stucco feels to the touch as smooth as glass.

Cornices are plain or ornamented, and sometimes embrace a portion of both. As to ornamental plastering a better taste has now developed itself, founded on principles derived from the study of the antique, than has heretofore been practised. The preliminaries to forming cornices in plastering consist of examining the drawings, and measuring the projections of the members, and if they should be found to project more than seven or eight inches bracketing will be necessary. It consists in affixing up pieces of wood about eleven or twelve inches from one another all round the place intended to have a cornice, and lathing over them with laths, and covering the whole by one coat of plastering, making allowance in the brackets for the stuff necessary to form the cornice: about one inch and a quarter is generally found sufficient. When the cornice has been so far forwarded, a mould is to be made of the profile or section of the cornice, exactly representing all its members; this is generally prepared by the carpenters (but at the plasterer's expense) of beachen wood, and of about one quarter of an inch in thickness; all the quirks or small sinkings being put in with brass. When the mould is done the plasterer examines it, and rubs and files off all the sharp edges, and opens with his knife such parts as he finds not adapted to leave the plaster well in the cornice. When the mould is ready the work of running the cornice with it is commenced. Two workmen are necessary for the operation; they are provided with a tub of *set* or *putty*, and a quantity of *plaster of Paris;* but before they begin with the mould they gauge a *straight line* or *screed* on the wall and ceiling made of putty and plaster, extending so far on each as to answer to the bottom and top of the cornice to be formed. On the *screed* so made on the wall, they nail one or two slight deal straight-edges, and make a notch or chase in the wooden mould of the cornice for it to fit into. This is the guide for moving the mould upon. When all is so far ready, the putty is to be mixed with about one-third of plaster of Paris, and rendered together of a semi-fluid state, by being diluted with clean water. One of the workmen now takes two or three trowels-full of the prepared putty upon his hawk, which he holds in his left hand, having in his right a trowel with which he plasters it over the parts where the cornice is to be formed, the other workman applying the mould to see where more or less of it is required; and when sufficient has been put on to fill up to all the parts of the mould, the workman, whose business it is to work the mould, moves it backwards

wards or forwards, holding it up firmly to the ceiling and wall, and which has the effect of removing the superfluous stuff, and leaving the exact contour of the cornice required, formed in plaster against the wall and ceiling. This is not effected the first time, but the other workman keeps supplying fresh putty to all the parts which he sees, by the moving of the mould, is in want of it; and by thus going on, the one working the mould, and the other adding putty, a piece of cornice is soon formed of from ten to twelve feet in length, or shorter or longer, as they generally endeavour to finish all the lengths or pieces which happen between breaks or projections at the same time, in order to its being more correct and true. If the stuff gets too stiff by delay in working the mould, one of the workmen sprinkles it with water from a brush, and this is frequently the case in large sized cornices, as the plaster occasions a very great tendency to fixation in the putty. When the cornices are of very large proportions, as is sometimes the case in the application of the orders of architecture, three or four moulds are requisite, and they are applied in the same manner until the whole composition of its parts are formed. The mitres, internal and external, and also small returns or breaks are afterwards modelled and filled up by hand; the plasterer piques himself much on the performance of this part of the work.

Ornamental Cornices are formed previously, and in a similar way to those above described, except that the plasterer leaves indents or sinkings in the mould to allow of the casts being fixed in. The plasterers at this time cast all their ornaments in plaster of Paris, whereas originally they were performed by hand, by artists, known in the trade as *ornament-plasterers*. Casting the ornaments in a mould has almost superseded this branch of art, as those few which are left are confined wholly to modelling and framing moulds to cast out of. The most ingenious in this way is Mr. Bernasconi, and those under him. This artist has been engaged by architects of known taste, and there are to be seen, in his gallery, capitals of the best Greek orders, embracing, perhaps, as much of the spirit of the originals as can be accomplished in plaster. Indeed, every thing done by him is like the work of an artist. All the ornaments which are cast in plaster of Paris are previously modelled in clay, exactly representing what is required by the design and drawing. The clay model exhibits the power and taste of the designer as well as that of the sculptor. When it is finished and got somewhat firm, it is oiled all over, and put into a wooden frame, which it is adapted to fit into; and all its parts are then re-touched and perfected, in order to their receiving a covering of melted-wax, which is poured warm into the frame and over the clay mould, where it is allowed to cool and fix itself. It is, when cool, turned upside down, and the wax comes easily away from the clay, and is an exact cameo of it. In such a mould are cast all the enriched mouldings, which are performed by the common plasterer. The waxen models are made so as to cast about one foot in length of the ornament at a time, these being found easily to be gotten from out of the cameo. The casts are all made with the finest and purest plaster of Paris, saturated with water, and the waxen mould is oiled previously to pouring it in to form them. The intaglios or casts, when first taken out of the mould, are not very firm, and are suffered to dry a little either in the air or in an oven adapted for the purpose; and when hard enough to bear handling, they are scraped and cleaned up for the workmen to fix in the place for which they were intended. Such is the process adapted by plasterers in casting ornamental mouldings.

The friezes and basso-relievos are performed exactly similar, excepting that the waxen mould is so made as to allow of a ground of plaster being left behind the ornament, of half an inch, or more, in thickness; this is cast to the ornament or figure, and strengthens and secures their proportions and promotes their general effect when fixed in the places for which they are intended.

Capitals to columns are got up in a similar way, but will require several moulds to complete them. To make a good capital will demand the utmost exertion of the modeller; he must *feel* before he can execute them with success. The Corinthian capital will require a shaft or bell to be first made, exactly shaped, to promote a graceful effect to the foliage and volutes, all of which, as well as the other details, will require separate and distinct cameos when they are intended for the capital to an order, as they are detached when fixed upon its shaft.

The most beautiful capital perhaps ever executed, and which approximates in its general character to what is generally known as the Corinthian, is that to the Choragic monument of Lysicrates at Athens. This capital has been successfully modelled and executed in plaster of Paris by the before-named Mr. Bernasconi.

The plasterers, as before mentioned, in performing cornices in which ornaments are to be used take care to have projections in the running moulds; these have the effect of leaving a groove or indent in the cornice; into this groove is put the ornament after it is cast, and it is fixed in its place by having a small quantity of liquid plaster of Paris spread on its back part. Friezes are prepared for, in the cornices, &c. in a similar way, by leaving a projection in the running mould at that part of the cornice where they are intended to be inserted, and they are also fixed in their places by liquid plaster. Detached ornaments, when designed for a cieling or any other part to which no running mould has been employed are cast in pieces exactly corresponding with the design, and fixed upon the cieling or other place by white-lead.

Plasterers require a great many models in wood, as there is very little of their finishing process completed without them. But with a mould a good plasterer is capable of making the most exquisite mouldings, possessing a sharpness and breadth unequalled by any other mode now practised. But this is in some measure dependent on the truth of the moulds. Good plastering is known by its exquisite appearance both as to regularity

regularity and correctness, its *solid* effect, with no cracks or indications of them, in words *plano*, *plano convexo*, or *plano concavo* may be taken as its symbolic character.

Stucco-making and working has for a considerable time employed the ingenuity of several descriptions of persons, viz. architects, chemists, physicians, and plasterers; but in our climate little good has been effected by their experiments, excepting the teaching of a better understanding of the materials employed in it. The common stucco now made for external work is composed of cleanly-washed *Thames sand* and *ground Dorking lime*, which are to be mixed in a dry state in the proportion of three of the latter to one of the former and when they have been well diffused one with the other, the compound should be put into casks and secured from the air. This is called among the plasterers *Bailey's Compo*. The process of using it on bricks or other walls consists in first preparing the parts to be covered with it by raking the mortar from out of all the joints and picking over the bricks, &c. themselves, till the whole of the wall appear indented. It is then to be brushed to free it of all dust and other superfluous matters which may be hanging about it; after which it must be sprinkled and washed over with clean water, and when wrought to this state the wall is ready to receive its first coat. This part of the work is called by the plasterers *roughing in*. It consists in diluting to *excess* the stucco in pails of water, till it is little stiffer in consistence than common *white-wash*. With stucco of this description the workmen rub over the whole of the wall by means of a flat hogs' hair brush, after which it must be left till it becomes tolerably dry and hard, which is known by its getting more white and transparent than when first done. The finishing of this kind of stucco-work is commenced by a process similar to what has been previously described for floated plastering, viz. by the forming of *screeds*; to do which the stucco is brought in casks, and tempered and saturated with water, and when deemed of a consistence proper for the work, some of it is spread on the wall to about eight or nine inches wide, and against its two outward or extreme ends, first extending from the top to the bottom of the wall. Two workmen are required to do it, the one in supplying the stucco, the other in using and trying the plumb-rule and straight-edge. When the *screeds* are formed and found to be quite true, others will require to be made and usually at every four and five feet distance from each other, unless it should happen that the apertures prevent it, in which case they must be formed as near together as possible. When the screeding is done, the wall will appear with sundry vertical stiles of detached stucco on it. These are the screeds, and will be the guides to the workmen in getting the wall covered over neatly and truly in stucco. More *compo* is now to be prepared, and in larger quantities than was wanted for the screeding; and when the stucco is ready, both the workmen begin by spreading it with their trowels over the wall in the space left between each two of the screeds which are nearest together, and when this space is filled up flush to them the straight-edge is applied across both, and dragged from the top to the bottom, which removes and brings away all the superfluous stucco which projected above the screeds. To the hollow and uneven parts fresh stucco is added, and the rule again applied and dragged backwards and forwards until the stucco completely raises itself up to the face of the screeds, and answers correctly to the edge of the rule; and so the workmen go on until all the spaces left between the screeds are filled up flush to them with the stucco, and the whole wall becomes entirely covered over with it. As the work proceeds thus gradually, space after space, one part will be done before another is; this is found to be a convenience, inasmuch as it admits of those parts which have been done first getting somewhat more dry than the others, which allows the final finishing to be proceeded in without any delay. The finishing to this kind of stucco-work consists in *floating* or hardening its surface by rubbing it with a wooden float and sprinkling it with water. This operation is similarly performed to the method before described for *trowelled stucco*.

Cornices or mouldings are formed in this kind of stucco by plasterers in the same manner (by moulds and screeds) to what has been before explained for doing them in common plastering. But the workmen find it essential to add a small quantity of plaster of Paris to the stucco, in order to produce a greater degree of fixation to it while running or working the mould. This is not much calculated to add strength to the stucco, and is only employed from necessity.

The patent stucco of Dr. B. Higgins had considerable reputation about thirty years since, and was employed by the Messrs. Adam in several places, but particularly in their great work to the Adelphi. It was composed of 14 or 15 pounds of choice stone lime, 14 pounds of bone ashes finely powdered, and 98 pounds of clean sand, fine or coarse according to the work intended, mixed up into mortar as quickly as possible with lime water, and used as soon as made. Altogether, there are about forty different suggestions and modes of forming the same materials into stucco, varying the proportions of each only, not one of which in this climate has been found to remain in a tolerably entire state above thirty years. Bailey's is the best common stucco now in use, and when done by himself is not very likely to fail, but it cracks and becomes unsightly in a few years. However, after all the toil and pains which had been taken on the subject by the titled superiors in science, it fell to the lot of a plain, and, we hope, honest man, without either an university or an academic distinction, to produce to his countrymen a cement embracing every requisite of durability, facility of working, and at the same time singularly capable of being formed with ease and expedition into every moulding or device in architecture and masonry. It is not too much to say of it, that it is the *ne plus ultra* of cements. This invention

tion was announced to the public by Mr. Parker, in June 1796, at which time he obtained letters patent for his invention. The way certainly in which he describes the nature of his new composition is liable to some objection from want of definiteness, but the object was obtained and he was satisfied. He says, nodules of clay or argillaceous stone generally contain water in their centre surrounded by calcareous crystals, and having veins of calcareous matter. They are formed in clay, and are of a brown colour like the clay. The nodules are directed to be broken into small pieces and burned in a kiln-like lime, with a heat nearly sufficient to vitrify them, and to be then reduced to a powder. Two measures of water to five of the powder makes *tarras*; lime and other matters may or may not be added, and the proportion of water may be varied. Mr. Parker's patent now having expired there are many other manufacturers of this cement, which are found to be of equal goodness in point of quality and some of them of rather a better colour, which is a recommendation, as the fresco-painting now used upon it when applied to buildings soon washes off by the rains and leaves it of a dark dingy and bad appearance. That made and sold by Mr. Cooke at Smart's Wharf, near Westminster Bridge, is of the lighter description of colour, and is of excellent quality. There are two qualities of this cement in use, the one *fine* and the other *coarse*; all the outsides of buildings are done with the latter, while the cornices and devices are formed of the former sort; the plasterers mix about one-fourth of washed sand with it when used for the stuccoing. The process of working it, if it be mechanically considered, is the same as for the other stuccoing; but no *roughing in* coat is required for it, as with this cement the work is done by the finishing process only of the other kinds. It is sold at all the wharfs and other depots in bags or casks by the bushel, varying from 4s. 6d. per bushel to 5s. 6d. for the coarser sort, and from 6s. 6d. to 7s. 6d. for the finest. The bags or casks to be returned or paid for at the option of the buyer of the cement. The bags usually contain three and the casks five bushels. It is perfectly impervious to water, and may be employed with success in the lining of tanks, ice-houses, and cisterns, in all of which cases the writer of this article has employed it with the desired effect.

The *Frescoing or staining* to the walls when stuccoed with this cement to make them represent the masonry of building, is done by diluting *sulphuric-acid*, or, as it is called in the shops, *oil of vitriol* with water, by putting into the fluid ochres, &c. to vary the tint of the fresco to the taste of the proprietor or painter of the work. Of this kind of paint various shades of colours are made, with which the stucco is painted over in pieces representing stone work, and the affinity existing in the iron of the cement ceases, and fixes the acid and colour it suspended in and upon the stucco, and renders its exterior appearance more agreeable to the eye, and at the same time resembling the ashlering bond of masonry. Some of the workmen do this so adroitly as to cause a doubt at first viewing it, whether it be cemented or not. Mr. Bernasconi is the most distinguished for using the cement and frescoing this kind of stucco work.

Rough-casting is an outside finishing cheaper than the stucco; from which circumstance it is more frequently employed on cottages and farm-buildings than in the better description of houses. It consists in the first place in giving the wall to be rough-casted a pricking-up coat of lime and hair, and when this is gotten tolerably dry it has a second coat of the same material added to it, which is laid on the first, and as smooth and even as it can be spread, and as fast as this coat is finished a second workman follows the one who is doing it with a pail full of rough-cast, which he casts on the new plastering. The rough-cast is composed of fine gravel with the earth washed cleanly out of it, and afterwards mixed with pure lime and water till the whole together be of a semi-fluid consistence; it is then spread or rather splashed upon the wall by a float made of wood. This float is five or six inches long and as many wide, of half-inch deal, to which is fitted a rounded deal handle. The plasterer holds this too in his right hand, and in his left a common white-wash brush, with the former of which he lays on the rough-cast, which is ready mixed as above, and with the latter which he dips in the rough cast also, he brushes and colours the mortar and the rough-cast he has spread, to make them when finished and dry appear even, regular, and of the same colour throughout.

Columns, &c. done in *Scagliuola* is a separate branch of plastering. The discovery was made in Italy, where much has been executed: it was from thence introduced into France, where it fascinated prodigiously all the cognoscenti of taste, and hence every thing became scagliuola. The first introduction of it into England was by the late Henry Holland, who brought the artists from Paris to perform it, some of whom, from finding there was a demand here for their labour, remained among us and taught our own workmen the art. The principal artist who now works in the scagliuola is Mr. Alcott, of Southampton-place, New Road; and as the demand of late has prodigiously increased he has taken in many additional persons, and taught them the making and working of the scagliuola. To execute columns and their antæ or pilasters in this kind of plastering require the following preliminaries. When the architect has furnished the drawing exhibiting the diameter of their shafts, a wooden cradle is made composed of thin strips of deal or other wood, about two and a half inches less in diameter than the column is intended to be when it is completed. This cradle is lathed all round, as is done for common plastering, and afterwards covered by a *pricking-up coat of lime and hair*, and when this is gotten *quite dry* the artists who work in scagliuola commence their portion of the business. It must be remarked here that the scagliuola is capable of imitating beyond discovery (except by actual fracture) the most scarce and precious marbles; any stone

stone partaking of the quality of marble may be exactly imitated in it, the imitation taking as high a polish, and feeling to the touch as cold and solid as the compactest and densest marble. To perform this the workmen are anxious to obtain the *purest* gypsum, which they usually select themselves, and after breaking it in small pieces calcine it. The fire is withdrawn as soon as they perceive that the largest fragments have lost their brilliance, and that the whole mass is become opaque and of the same colour. The calcined powder is then passed through a very fine sieve, and mixed up as it is to be used with a solution of Flanders glue, isinglass, &c., and it is in this solution that they diffuse the colours required in the marble they are about to imitate. But when the work is to be of various colours, they prepare each separately, and afterwards mingle and combine them nearly in the same manner as a painter mixes on his pallet the primitive colours which are to compose his different shades. When the powdered gypsum or plaster is prepared and mingled for the work, it is laid on the shaft of the column, &c., covering over the pricked up coat which has been previously laid on it, and is floated with moulds of wood to the size required, the artist using the colours necessary for the marble it is intended to imitate during the floating, and which becomes mingled and incorporated in it. In order to give his work the polish or glossy lustre so much admired in works of marble, he rubs it with a pumice-stone in one hand, while with the other he cleanses it by means of a wet sponge. He next proceeds to polish it with tripoli and charcoal, and fine soft linen, and after going over it with a piece of *felt* dipped in a mixture of oil and tripoli, finishes the operation by the application of pure oil.

Hence is effected perhaps one of the completest imitations in the world, and when the capitals and bases of columns so performed are made of *white* or other kinds of *real* marble, as is the common practice, the deception is past a discovery. It is also as strong and as durable as real marble for all works not exposed to the effects of the atmosphere, retains its lustre as long and equal to real marble, and is not one-eighth of the expense of the cheapest imported.

There is a species of plastering practised in the trade and known to the public as *Composition*, or *Composition-Ornament*. This is done by a distinct set of persons, and consists in the making of all kinds of ornaments, not only for the decorative part of architecture, but for picture, glass frames, &c. &c. The composition for this work is of a brownish colour exceedingly compact, and when completely dry very strong. It is composed of powdered whitening, glue in solution, and linseed-oil; the proportions of which are, to two pounds of whitening and one pound of glue, half a pound of oil is added. These are placed in a copper and heated, stirring it with a spatula till the whole becomes incorporated. It is then suffered to cool and settle; after which it is taken and laid upon a stone covered with powdered whitening and beaten till it become of a tough and of a firm consistence. It is then put by for use, covered by wetted cloths to keep it as it is called *fresh*. The ornaments to be cast in this composition are modelled in clay, as is done for common plastering; and afterwards a cameo or mould is carved in a block of box-wood. The carving the cameo is done with great neatness and truth, as on it depends the exquisiteness of the ornament that is to be cast in it. The composition when it is to be used is cut with a knife into pieces adapted to fill the mould, and is closely pressed by hand into every part; it is then carried and placed in a press worked by an iron screw, and by which it is further pressed till it is supposed to be forced into every part of the sculpture of the cameo: after which it is taken out of the press, and by giving it a tap upside down only it comes easily away and out of the mould. One foot in length is as much as is usually cast at a time, and when this is first taken from out of the mould, all the superfluous composition is removed by cutting it off with a knife; the waste pieces being thrown into the copper to assist in making a fresh supply of composition. This composition when formed into ornaments is fixed upon wooden or other ground by a solution of heated glue, white lead, &c. It is afterwards painted or gilded to suit the taste and style of the work for which it is intended. The best plasterer in this line was the late Mr. Thorp of Princes-street, St. Anns; and the work appears now to be equally well performed by his successor Freeman. It is at least 80 per cent cheaper than carving, and in many cases equally well calculated to answer every purpose to be derived from it.

The measuring and valuing plasterers' work is conducted by persons known in the trade as measurers, to the public as surveyors. All common plastering is measured by the *yard square* of nine feet; this includes the partitions and cielings of rooms, stuccoing in and externally, &c. &c. Cornices are measured by the foot superficial, girting their members to ascertain their width. Their length is the length of the cornice. The Running measures consist of beads, quirks, arrises, and small mouldings. Ornamental cornices are frequently valued in this way also, viz. by the *foot run*.

The labour on plasterers' work is frequently of more consideration than the materials; hence a cautious master is particular in noting down the exact time his men may take in performing their respective pieces of plastering, in order to an adequate value being put upon the work commensurate to its difficulty.

PLUMBERY.

PLUMBERY.

PLUMBERY embraces a certain portion of hydraulics, as well as casting and laying of sheet-lead as a covering on buildings. To the plumber is confided the pump-work, as well as the making and forming reservoirs, large and small, for all the purposes of our domestic economy. To him, also, we are indebted for the water-closet, a delicate apparatus adapted to every situation; the utility of which, in as far as delicacy is concerned, is too obvious to need observation: it is of English invention, and was unknown on the Continent till the Peace of Amiens allowed of its exportation.

The plumber chiefly works in lead. This metal is known in the Arts, from its durability, maleability, and many other properties, which renders it of the very highest importance. Lead is of a bluish-white colour, and, when newly melted, very bright, but it soon becomes tarnished by exposure to the air. Its hardness is $5\frac{1}{2}$, its specific gravity is 11,3523. It may be reduced by the hammer to very thin plates, it may also be drawn out into wire; but its tenacity is not great if compared with many of the other metals. A lead wire $\frac{1}{120}$ inch diameter is capable of supporting 18:4 pounds only without breaking. Lead melts when heated to the temperature of 612 of Fahrenheit, and when a strong heat is applied the metal boils and evaporates. If it be cooled slowly it crystallizes. When exposed to the air it soon loses its lustre, and acquires at first a dirty grey colour, and, finally, its surface becomes almost white. This is owing to its gradual combination with oxygen, and conversion into an oxide; but this conversion is exceedingly slow. The external crust which forms first, preserving the rest of the metal for a long time, from the further action of the air. Water has no direct action upon lead, but it facilitates the action of the external air; for when lead is exposed to the air, and kept constantly wet, it is oxidated much more rapidly than it otherwise would be. Hence the reason of the white crust which appears upon the sides of leaden vessels containing water just at the place where the upper surface of the water terminates.

Lead is obtained from the mines, and is almost always combined with sulphur, and hence it is called a *sulphuret*. The operation of roasting the ore, or smelting, as it is called, to obtain the pure metal consists:— 1. In picking up the mineral to separate the unctuous, rich, or pure ore, and the stony matrix, and other impurities. 2. In pounding the picked ore under the stampers. 3. In washing the pulverized ore to carry off the matrix by the water. 4. In roasting the mineral in a reverberatory furnace, taking care to stir it, to facilitate the evaporation of the sulphur. When the surface begins to become of the consistence of paste, it is covered with charcoal, the mixture is shaken, the fire increased, and the lead then flows down on all sides to the bottom of the basin of the furnace, from which it is drawn off into moulds or patterns, prepared to receive it. The moulds are made so as to take a charge of metal equal to one hundred and fifty-four pounds; these are called, in commerce, *pigs*, or pigs of lead, and are exported, and sold as such at the depots, by the lead merchants.

The plumbers use lead in sheets, and of these they have two kinds; one of which they call *cast*, and the other *milled lead*. The cast lead is used for the purpose of covering the flat roofs of terraces of buildings, forming gutters, lining reservoirs, &c. In architecture it is technically divided into 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$, 7, $7\frac{1}{2}$, 8, and $8\frac{1}{2}$ lbs. cast-lead, by which is understood, that to every *foot* superficial of such cast-lead, it is to contain these several weights of metal in each respectively; so that an architect when directing a plumber to cover or line a place with cast sheet-lead, tells the workman that "it is to be done with 6 or 7 lb. lead;" meaning by it, that he expects each foot superficial of the metal to be equal in weight to six, seven, or other number of pounds. The plumbers sometimes attempt deception in this arrangement, and particularly in work agreed for by contract, by putting down a lighter metal than the one they have engaged to do. The writer of this article has once or more had occasion to interfere in such attempts, and has had the whole of such lead removed, not finding it adequate in weight per foot to that which was contracted for.

Every plumber, who conducts business to any extent, casts his sheet-lead at home; this he does from the pigs, or from old metal which he may have taken in exchange. The ductility of lead renders it easily to be run, which they do with considerable address. To perform which they provide a copper, well fixed in masonry, and placed at one end of their casting-shop, and near to the mould or casting-table. The casting-table is, generally, in its form, a parallelogram, varying in its size from six feet in width to eighteen or more feet in length. It is raised from the ground as high as to be about six or seven inches below the top of the copper which contains the metal, and stands on strongly framed legs, so as to be very steady and firm. The top of the table is lined by deal boarding laid very even and firm, and it has a rim projecting upwards, four or five inches all

all round it. At the end of the table, nearest to the copper in which is the heated lead, is adapted a box equal in length to the width of the table, at the bottom of this is made a long horizontal slit, from which the heated metal is to issue when it is to be cast into sheets. This box moves upon rollers along the edges of the projecting rim of the table, and is set in motion by ropes and pulleys fixed to beams over the table. As soon as the metal is found to be adequately heated, every thing is gotten ready to cast it on the table, the bottom of which is then covered by a stratum of dry and clean sand, and a rake is applied to smooth it regularly all over the surface. When this is done the box is brought close up to the copper. It must be observed, that these boxes are made, in their contents, equal to the containing of as much of the melted lead as will cast the whole of the sheet at the same time, and the slit in the bottom is adjusted so as to let as much, and no more, out during its progress along the table, as will be sufficient to cover it completely of the thickness and weight per foot required. When the box has dispersed its contents upon the table, it is suffered to cool and congeal, when it is rolled up and removed away, and other sheets are made till all the melted metal in the copper be cast up, and it is emptied. The sheets so formed are rolled up and weighed, as it is by weight the public are charged for sheet-lead.

The other kind of sheet-lead made use of by plumbers, called, in the trade, *milled lead*, is not manufactured at home. This they purchase of the lead merchant, as it is cast and prepared commonly at the ore and roasting furnaces. Such kind of lead is very *thin*, and commonly there is not more than four pounds of metal to the foot superficial. It is used by architects for the covering only of the hips and ridges of roofs of buildings. It is by no means adapted to gutters or terraces, or, in fact, to any part of a building much exposed either to great wear and tear, or the effects of the sun, as it expands and cracks by the latter, and is soon worn away by the former exposure. It is laminated in sheets about the same size as has been described for cast sheet-lead; and, in the operation of making, a laminating-roller is used, or a flatting-mill, which reduces it to the state in which it is seen in commerce.

Solder is used by the plumber for the purpose of securing the joints of leaden work, in cases in which a *lap* or *roll-joint* cannot be employed. It is a general rule with respect to solder, that it should always be easier of fusion than the metal intended to be soldered by it. Next to this, care must be taken that the solder be as far as it is possible of the same colour with the metal intended to be soldered. Technically, the soft *solder* is that which the plumber makes use of, by reason of its melting easily. This solder is composed of *tin and lead*, in equal parts, fused together; after which it is run into moulds in shape not unlike a common gridiron. In this state it is sold by the pound by the manufacturer. In the operation of soldering, the surfaces of the metal intended to be joined are scraped and rendered very clean, they are then brought close up to each other, and, to secure them, they are held by one plumber while another lays a little resin or borax about the joint. This is done to defend the metal, while soldering, from oxidation. The heated solder is then brought in a ladle and poured on the joint to be soldered, and is smoothed and finished by rubbing it about with a heated *grozing-iron*, and when complete, it is filed or scraped off, and made even with the joint and contiguous surface of the lead.

The plumber has no need of great variety of working tools, as the ductility of the metal he works in does not require them, and what he may require are generally supplied by the master-tradesman. They consist of an iron hammer made rather heavier than they usually are seen, having a short but thick handle. Two or three different sized wooden mallets, and a dressing and flatting tool. This instrument is made of beechen wood, commonly about eighteen inches long, and two inches and a half square, planed quite smooth on one side, and rounded into an arch on the other, or upper side. One of its ends is tapered and rounded to make it convenient to be held in the hand of the workman. With this tool the plumber stretches out and flattens all the sheet-lead, as well as dresses it into the shape it may be wanted in the various purposes to which such lead is applied, using first the flat side of this tool, and then the round side, as may be required. They have also a *jack* and *trying* plane, similar to the same kind of tools used by carpenters. These tools consist of a piece of beechen wood, that for the former about sixteen inches, and, for the latter, twenty-two inches long, in each of which a flat iron of sharpened steel is fitted, and held to its work by wooden wedges adapted to mortises made at the distance of about one-third from the fore-end of each plane. At the opposite end is formed a handle by which the planes are worked. With such tools plumbers plane straight the edges of their sheet-lead, when it is required to present a very regular and correct line, as it is frequently wanted to do in architecture. They are provided also with a line and roller, called a *chalk-line*; with this they line out all the lead into the different widths it may be wanting. Their cutting tools embrace chisels and gouges of different sizes, as well as several cutting knives. These latter are used for the purpose of accurately cutting the sheet-lead into the strips and pieces to the division marked by the chalk-line which has been drawn on the lead. They have files of different sizes, which they use in manufacturing of cistern leads to pipes, pump-work, &c.

For soldering, they keep a variety of different sized grozing-irons; these are commonly about twelve inches long, and tapered at both ends, the handle-end turned quite round to allow of its being held firmly in the hand while in use. The opposite ends of which are made spherical, and some of them are of a spindle-shape, and of a size in proportion to the soldering to be done with them. These kind of irons are heated to redness when used.

used. Their iron ladles are of three or four sizes, and used for the purpose of heating the solder.

A plumber's measuring rule is of two feet in length, divided into three parts, each of which is eight inches long. Two of its legs are of box-wood, and duodecimally divided, and a third of a piece of slow-tempered steel; this is attached to one of the box legs by a pivot, on which it turns, and the same legs being grooved out on its side it receives the steel leg, when not in use, in this groove. The plumber finds a rule of this description very convenient, inasmuch as he can pass the steel leg of his rule into places he may have to examine, which he could not readily get any thing else to enter: it also answers the purpose occasionally of removing the oxide or any other matter from off his heated metal. A plumber's rule, by being so made, is constantly in use in one way or another.

Scales and weights are also very essential, as nothing done by the plumber is chargeable till it be weighed. He is also supplied with centre-bits of all sizes, and a stock to work them in, for the making perforations in lead or wood, where he may have occasion to insert pipes, &c. &c. The compasses he uses occasionally to strike out any circular portion of lead wanted to line or cover figures of that description.

Of laying Sheet-Lead.—The method usually adopted consists, if it be for terraces or flats, of covering such places with a bottom as even as possible, either by boarding or plastering; if, by the former, observing to have the boards thick enough to prevent their warping and twisting upwards, as, when this is not attended to, the lead work is soon cracked and becomes very unsightly. The sheets of lead not being more than about six feet in width makes it necessary to have joints when a large surface is to be covered; these joints the plumber manages in various ways to prevent them leaking. The best way is by forming what are called *rolls;* a roll consists of a piece of wood of about two inches square, planed rounding on its upper side, these are fastened under the joints of the lead between the edges of the two sheets which meet together, one of which is dressed up over the roll on the inside, and the other over both of them on the outside, by which means the water is prevented from percolating the flat. No other fastening is required than the adherence of the lead by being closely hammered together, and down upon the flat: indeed, all fastening to the sheet lead, exposed to heat and cold, ought to be avoided, as it expands and shrinks by such vicissitudes, and if secured so as to prevent these from spontaneously effecting it, it will be cracked and dilapidated quickly. When rolls are not used, which is sometimes the case from their being found inconvenient by their projection, *seams,* as they are called, are employed, and consist in simply bending the two edges of the lead which approach to each other up and again over one another, and then dressing them down close to the flat throughout their whole length. This plan is by no means equal to the one by the roll, either for neatness or security. Soldering the joints is sometimes had recourse to for such kind of work, but it is a very bad way, and no good plumber would recommend it, as lead so fixed will be cracked and leak like a sieve, after having been exposed to one summer's sun. Leaden-flats, as well as gutters, require to be laid with a current to keep them dry. The rule for forming of which consists in giving a fall from back to front, or in the way in which it is determined that the sheets of lead are to be laid. A quarter of an inch to the foot run is a sufficient fall for lead, that is, if the sheets be twenty feet long, and hence they will require to be laid five inches higher at one end than at the other. This inclination, or, as it is called, giving a *current,* is generally apportioned and determined on by the carpenter and plumber previously to the laying of the lead, while the former's part of the business is doing.

Flashings, as they are called, are pieces commonly of milled-lead about eight or nine inches wide, and fixed all round the extreme edges of a flat or gutter, in which lead has been used. If a wall of brick-work surround it, it is passed into the joint between the bricks and its other edge, dressed over that of the edge of the lead in the flat or gutter, and when no joint can be found to receive its upper edge, it is then fastened by wall-hooks, and its other edge dressed down as before.

Drips in Flats or Gutters consist in raising one part above another, and dressing the lead as has been described for covering the rolls. They are had recourse to when the lengths of the gutter or flat exceed that of the length of the sheet, or sometimes for convenience; they are also an expedient to avoid joining the lead by soldering it.

The pipes used by the plumber are of various sizes as well as description. All the smaller sizes are called by their caliber or bore, thus, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 1^3, and 2-inch pipe. They originally used to be cast by a core of wood of these respective diameters, but they are now all made by a machine worked by steam, which furnishes a neater article of almost any length, and considerably more cheap than heretofore. All those pipes, from $\frac{1}{2}$, to $1\frac{1}{2}$-inch caliber, are charged by the foot run, and those above that size by the hundred weight. The rain-water pipes attached to the outside of buildings for the purpose of conveying off the superfluous water from the roofs of them, called, by the plumbers, *socket-pipes;* of these several respective diameters is 3, $3\frac{1}{2}$, 4, or 5 inches, and are made from sheet-lead, and most commonly from that which is called milled. They are formed in lengths of from eight or ten feet each; the sheet-lead for making which is dressed on a rounded core of wood, and the vertical joint which is made at the back is fastened and secured by solder. The horizontal joints are formed by an astrigal moulding in a separate piece of lead about two or three inches wide, and which laps completely over it, both above and below it, and is called the *lap-joint,* or collar of the socket-pipe. Two broad pieces of lead are attached to the back of the lap-joints, called the *tacks,* these are spread out right and left of the pipe upon the wall to which they are hammered

hammered quite close, and answer the purpose of fixing the whole to the buildings: to do which, more effectually, wall-hooks of iron are sometimes put, and driven into the masonry. The cistern-head, which is fixed at the top of rain-water pipes, is made up of sheet-lead, or cast in a mould. They are commonly moulded into a variety of forms, these are easily supplied in a metal so ductile as lead is: they are fastened by tacks in the same way as the collars are.

Reservoirs are generally formed of wood or masonry on their exterior, and their insides lined with cast sheet-lead, the joints of which are secured by solder. In this application of soldering no fear of cracking need be anticipated, as change of temperature seldom takes place in or near the place where reservoirs are commonly placed.

Pumps are of various descriptions, and employed for purposes multiplied and extensive; but the plumber's employment in this kind of work is confined generally to the making of two or three several kinds, as may be required in our domestic economy. These may be considered as the sucking, forcing, and lifting pumps. The former and latter being now the most commonly made use of.

The Sucking-Pump consists of two pipes, one of which is the barrel, and the other the suction-pipe, which is of smaller diameter; these are joined by means of flanches pierced with holes to admit of being fastened by screwed bolts. The joint of the flanches is filled with leather, which being strongly compressed by the screwed bolts, renders the joint air-tight. The lower end of the suction-pipe is commonly spread out a little to facilitate the entry of the water, and frequently has a grating across it to keep out filth or gravel. The working barrel is cylindrical, and as evenly bored as possible, that the piston may fill it with as little friction as may be consistent with air-tightness.

The piston is a sort of truncated cone generally made of wood, the small end of which is cut off at the sides, so as to form a sort of arch, and by which it is fastened to the iron rod or spindle. The two ends of the conical part may be hooped with brass: this cone has its larger end surrounded with a ring or band of strong leather fastened to it by nails. The leather-band should always reach to some distance beyond the base of the cone, and the whole must be of uniform thickness all round, so as to suffer equal compression between the cone and working barrel when put into action. The seam or joint of the two ends of this band must be made very close, but not screwed or stitched together; if done so it would occasion lumps or inequalities, which would destroy its tightness, and no harm can result from the want of it, because the two ends will be squeezed close together when in the barrel. It is by no means necessary that this compression be great; when it is so, it is found a detrimental error of the pump-maker, by occasioning enormous friction, which destroys the very purpose they have in view, viz. rendering the piston air-tight; and it moreover causes the leather to wear through very soon at the edge of the cone, and also wears away the working barrel; in consequence of which it becomes wide in that part which is continually passed over by the piston, while the mouth remains of its original diameter, and hence follows the impossibility to thrust in a piston that shall completely fill the part so worn away.

The suction-pipe is usually made of smaller size than the working barrel, but only for the sake of economy, as it is not necessary that it should be so; but it ought to be of such a size that the pressure of the atmosphere may be able to fill the barrel with water as fast as the piston rises.* This is the kind of pump fixed and made by plumbers, and is that which is commonly seen over wells and reservoirs for the purpose of raising water for the common purposes of life.

The *Forcing-Pump* consists of a working barrel, a suction-pipe, and a main, called *serving main*, or raising pipe. This kind of pump was formerly much in use for the purpose of forcing water to unnatural heights. The raising pipe of such pumps is usually in three parts, the first of which may be considered as making part of the working barrel of the pump, and is sometimes cast in one piece, with it the second is joined to it by flanches, with which it forms an elbow. The third is properly the beginning of the main, and is continued forward to the place of the delivery of the water where it is supplied by two moveable valves. The beauty of this kind of pump consists in the perfection of the barrel and piston, for which reason it is now made of brass or bell metal, and when it is well polished the piston may be used in it without either a wadding or leather.

The Lifting-Pump consists as before of a working barrel, which is closed at both ends. The piston is solid and its rod passes through a collar of leather in the plate, and closes the upper end of the working barrel. The barrel communicates laterally with the suction-pipe, and above with the raising main. This kind of pump differs only from the sucking-pump before described in having two valves, the lower one moveable and the upper one fixed.

The first pump invented above a century before Christ by Ctesibius, of Alexandria, to whom also music is indebted for the organ, was a forcing-pump, as may be easily collected from its description by Vitruvius (l. x. cap. 12).

Mixed Pumps are the combination of the principle of the forcing and sucking-pumps into one machine; when the lower valve of a forcing-pump is above the surface

* The length of the suction-pipe should never be greater than thirty feet below its moveable valve, and there may be a loss of time in the ascent of the water, unless it be made even a few feet shorter. In using it the velocity of the stroke should never be less than four inches, nor greater than two or three feet in a second. The stroke should be as long as possible to prevent loss of water by the frequent alternations of the valves. When this pipe is adapted to common purposes, its diameter should be about two-thirds or three-fourths of that of the barrel.

surface of the water it can only raise it by suction, but the manufacture of the pump remains as before. The mechanism of a pump may be employed for converting the weight of water descending in its barrel to the purpose of working another pump; such a pump has been invented by Mr. Trevithick, a description of which may be seen in Nicholson's Journal.

Of the Spiral Pump.—If we wind a pipe round a cylinder of which the axis is horizontal, and connect one end with a vertical tube while the other is at liberty to turn round and receive water and air in each revolution, the machine is called a *spiral pump*. This pump was invented about 1746, by Andrew Wirtz, a pewterer in Zurich, and was afterwards employed at Florence. At Archangelsky near Moscow, it is reported such a pump was erected in 1784, which raised a hogshead of water in a minute to a height of 74 feet, and through a pipe 760 feet in length. The force employed is not stated, we may therefore conjecture that it was turned by water.

The Screw of Archimedes, or Water Snail, and the Water Screw Pump, consist either of a pipe wound spirally round a cylinder, or one or more spiral excavations formed by means of spiral projections from an internal cylinder covered by an external coating so as to be water-tight. But if the coating is detached so as to remain at rest while the spirals revolve, the machine is called a *water-screw*. These kind of pumps are employed by the architects in removing superfluous water from out of the foundations of bridges or elsewhere. The screw of Archimedes should always be so placed as to fill exactly *one half* of a convolution in each turn. It has often happened that very unfavourable reports have been made of the power of this machine from want of attention to this circumstance; for when its orifice remains constantly immersed the effect is very much diminished. Where the height of water is so variable as to render this precaution impossible, the *water-screw* will be preferable, although in this instrument *one-third* of the water runs back, and it is easily clogged by accidental impurities in the water. The screw of Archimedes is generally placed when in action, so as to form an angle of between 45 and 60 degrees with the horizon; while the open water-screw will do at an angle of 30 degrees only. For great heights the spiral pump is preferable to either of the before-mentioned machines, as promoting a greater effect with less labour.

Pump-work will require a very *refined* calculation to develope its real powers. The machines here treated of are reduced to public purposes by having their details regularly manufactured to almost every required purpose, as such they are vended to the plumber and public.

Water-Closets are made in a similar way, manufactured by one set of workmen and sold to the plumber, who is another, to fix in their places. A water-closet consists of a bason and apparatus, traps, socket-pipe, and cistern; the whole of which is put into action by the plumber. To supply the cisterns with water is the purpose of his adopting a forcing or lifting-pump. These latter are on a small scale, very neatly fitted up, and require only the suction and main pipe to be added by the plumber, to be capable of forcing or lifting water to almost any height. They are sold by the manufacturers at 7l. 7s. each. The mains or pipes are charged by the plumber additional, with such day-work as is required in putting the whole in its place. The bason and apparatus to a water-closet is sold for 5l. 5s.; but the whole fitting up of such a convenience cannot be made, with all its pipes, for a less sum than 25l. to 30l. Plumbers charge their sheet-lead by the one cwt., and their prices are arranged half-yearly by the Warden and Court of Assistants of the Plumbers' Company. The milled-lead is always charged two shillings per cwt. more than the cast-lead.

POTTERY.

Pottery is the art by which plastic earth is converted into hard and brittle vessels of various kinds and forms, and designed for various purposes. The essential material of all potteries is clay, which, of itself, possesses the two requisite qualities of being in its natural state so plastic, that, with water, it becomes a soft uniformly extensible mass, capable of assuming and retaining any form, and when thoroughly dried, and having undergone a red-heat for a time, of losing this plasticity, and of becoming hard, close in texture, and able more or less perfectly to confine all liquids contained within its hollow. The most important circumstances requisite to be considered in selecting the materials for pottery are plasticity, contractibility, solidity, and compactness after drying, colour, and infusibility.

The *plasticity* seems to be simply owing to the proportion of clay used, or the nature of the clay itself, for all clays are, owing to their mixture with other substances,

stances, not equally plastic, and the foreign ingredients, in *no* case increase, but, in many cases, diminish this property in a very considerable degree.

The texture, including the qualities of hardness and compactness, depends partly on the mixture of siliceous or flinty ingredients, with the clay, and partly on the heat employed in the burning of the pottery. The very pure natural clays are infusible in almost any degree of heat, and their hardness keeps pace with the intensity of the fire, but they have the essential defects of drying very slowly, of shrinking much, and of becoming full of cracks when dried. On these accounts it is necessary to mix them intimately with some other earth or earths of different qualities; that is, with some that will absorb but little water: will quickly part with it, and will dry compact and close.

The colour of the earths used is also of essential importance in the finer pottery, in which the great desideratum is to find clay that, after burning, remains perfectly white. The appearance, before burning, cannot always be depended on; for, though the whitest clays, after burning, are those that were white before, yet it is only the clay of certain districts that retain a perfect whiteness. Thus, we are told, that there exists, at the foot of a range of hills that overlook the Staffordshire potteries, a stratum of white clay, which, to appearance, is fully equal to the best Devonshire clays, but which cannot be employed for fine pottery, from its acquiring, in burning, a yellowish cream-colour, which no art has yet been able to correct.

The fusibility of clays and other earths used in pottery is a subject of great importance, as it is property that constitutes the difference between common earthenware, as it is sometimes called, and porcelain.

We shall now proceed to give some account of the mixture and combination of the earths with respect to potteries.

None of the primitive earths, treated separately, present to us, as we have seen, the union of all the qualities necessary to form a good potter's clay; and it is also to the well-contrived mixture of some of the earths that we are indebted for this production of the arts. We shall comprehend under the general title of pottery, all the productions of the art, from the coarsest manufactory to that of the finest porcelain: the whole art consists in the proper mixing of two or three earths; the only difference in the results proceeds from the choice of the earths, from the care taken in their preparation, the proportions in which they are employed, and from the nature of the baking and degree of heat to which they are subjected. There are, therefore, some general principles which apply to all these operations; these are the principles which are necessary to be known, in order to adapt them to processes, which, though isolated and separated in practice, flow from the same laws, and should be elucidated by the same doctrine. We may regard alumine as the base of all the potter's earths; the property that it possesses, of dividing itself in water, and forming a paste susceptible of being manipulated, turned in the lathe, ground, &c., in order to assume easily and preserve all the forms we may wish to give it; the faculty which is peculiar to it, of becoming so hard in the fire that it will strike fire with steel; of scratching glass, and of uniting, by the application of a violent heat, so as to assume a smooth and almost vitreous surface without fusion; and of no longer being divisible or dilutable in water; have caused alumine to be adopted in preference to all the other earths. But this earth is not free from inconveniences; it contracts upon being fired, and can bear with difficulty a sudden transition from cold to heat. These defects are remedied by mixing it with sand or siliceous earth, which being infusible like itself, do not sensibly contract in the fire, and form a kind of frame, which, by isolating, as it were, the argillaceous particles, admits of their being subjected, without inconvenience, to the alternate transitions of heat and cold. Besides, the mixture of these two substances forms a kind of compound, the properties of which may differ from those of its constituent principles.

By examining more closely the principal qualities of baked earths, we shall perceive the reason of their greater or less resistance to being broken by the sudden change of temperature. In fact, it is known that the earthy substances are bad conductors of caloric; so that when we apply heat to the surface, it produces its effects of contraction or dilatation before it is able to penetrate to the same degree all the mass; it must, therefore, have unequal effects, which tend to break the whole. This must be still more sensible when the earthen-ware presents a great inequality of thickness. But when we multiply the pores, or the small apertures, by means of sand, the fluid of heat circulates more freely; the mass is more equally heated, and nearly at the same time; and the vessel resists alternate heat and cold. This property may also be given to it by applying the heat gradually; the changes then take place slowly, and at once, over all the parts. But the alumine is rarely pure, it is naturally mixed with lime, silex, magnesia, oxydes of iron, copper, manganese, &c.; and it is the nature of these mixtures, and the proportions among the bodies which form them, that give to argils a variety of modifications in their properties.

Among the number of these natural mixtures, there is one of them which only requires the hand of the potter to shape it into useful utensils. For this reason, we see manufactories of coarse earthen-ware established upon the very stratum of clay which supports them; but more frequently these argils require a particular operation, and must be mixed with other earths to make them of use for the purposes for which they are wanted. In general, it is only from well conducted experiments that we judge of the quality of an argil, and that we determine the nature and proportions of the substances most proper to add in order to make it fit for producing good ware. It is almost needless to observe, that we must not expect the same qualities for every

kind

kind of ware, since these qualities are relative to the different uses to which the ware is to be applied: thus, in order that an earth should be fit for making pipes for a drain, house-tiles, or bricks, it would be ridiculous to require that it should be able to resist great heat, or undergo the sudden transitions of heat and cold. In this case it is sufficient if the mixture acquires hardness enough to prevent water from softening or penetrating it.

Those wares destined to undergo a violent heat and sudden transitions of temperature, such as crucibles, retorts, furnaces, &c., should likewise have no attraction for the bodies which we intend to work in them. The ware employed in our kitchens would be of very limited use, if they did not undergo, without alteration, a sudden change of temperature, and if they were not compact enough to prevent liquids from filtering through them. When we possess a pure clay, furnished with the requisite qualities for forming the base of a good earthen-ware, we may apply it to every purpose, by well-contrived mixtures. It is necessary, therefore, to know the qualities which constitute a good clay, before we attend to the nature and proportions of the earths that we ought to mix with such as do not already possess qualities required.

A good clay has the following characters:—1st. It divides or melts in water without any nucleus remaining. 2d. It is precipitated in this liquid, without leaving any thing suspended which injures its transparency. 3d. The deposit which is formed in the water, dried to the consistence of a soft paste, should have so much toughness and ductility, that we may easily work it by a lathe, or by the hands. 4th. It should neither lose its form nor consistence on drying in the air. 5th. It should harden upon the application of heat, without cracking, without being deformed, or melted. 6th. It should undergo, when fired, the sudden transitions from heat to cold, and vice versa. A clay, possessing all these properties, is a natural mixture of various earths, for no one in particular possesses them all.

When a slight part of oxyde of iron, lime, or plaster, is united with the earth we are speaking of, the earthenware made from it presents a brilliant and vitreous gloss and fracture, at the same time that they acquire such a hardness that they strike fire with steel, and break nearly like glass. These wares sound well, as it is called, and they are capable of containing corrosive liquids, without being penetrated or altered by them. They would be the best earthen-wares known, if they could undergo, without accident, the sudden transitions of temperature. This is what is called stoneware; it resembles much the biscuit of porcelain, from which they do not essentially differ, except in the grain, the colour, and the semi-transparency. The most common argillaceous earth, which is called fat earth, and potter's clay, and of which the coarser ware is made, is a natural mixture of alumine, silex, lime, and a little oxyde of iron. The silex generally predominates; the alumine is in the proportion of about one-half: this is, at least, the mean result of a great many analyses.

When the argillaceous earth is too rich in alumine, it is usual to mix pounded flints or sand with it, in order to correct the defects of too pure argil. It has been ascertained, that if we mix sand with clay, it is more advantageous to employ that which is of a middling size. Frequently, in place of sand, fired clay is used: this mixture is preferable for the manufacture of crucibles and glass-house pots, which must keep alkalis in fusion, because these latter substances would attach the sand in order to form glass. When the clay contains pernicious substances, from which it must be freed, it is carefully examined, the ochery veins are thrown away, as also the pyrites, and other matters which alter its purity. By means of water, we may afterwards free it from the calcareous earth which floats above, and from the sand, which is precipitated. These are nearly all the general principles upon which the art of the potteries is founded; and, although there has been established in society, an enormous difference between the coarse earthen-ware which the common people use, and the porcelain with which the rich decorate their tables and ornament their apartments: *it is not less* true, that, in both cases, the nature, the preparation of the earths, and even the management of the fire, differ in some respects only. After having, therefore, related the principles which science presents to us as applicable to the art of the potter, it only remains to give some details essentially connected with each of the branches of the art.

The choice of the earths, and the proportions in their mixture, differ according to the nature of the works we mean to execute; but, when the choice and mixture are made, the working of the paste and the baking of the article, present a course of processes, in which there is no difference, except in the more or less care which the artist takes in these different operations. The preparation of the earths is always confined to giving them an extreme minuteness of division, by means of water, with which they are impregnated. They are disposed to this preliminary operation by reducing them into small fragments, or into powder, by means of mallets, of mills, or other mechanical methods. The water employed should be pure, particularly when delicate pieces of ware are to be made; for this reason, in some manufactories of porcelain, rain-water only is used. The earths are allowed to soak, or rot, as it is termed, for a longer or shorter period, according to the nature of the earth, and that of the work we wish to produce. The longer the earth is in the pit to soak, the better it is prepared. Not only are the bituminous or vegetable principles, which exist in some earths, destroyed, but any sulphuric salts they may contain, are decomposed; and it almost always happens, that, after some time, sulphuretted hydrogen gas is liberated. By their being allowed to remain some time in the pit, the earths acquire more tenacity and toughness, so that they can be wrought more easily. On

this account, in some celebrated manufactories in Germany, they soak the earth at two seasons in the year only, and the time of the equinoxes is chosen, because it is generally thought that rain-water is more strongly charged with fermentescible principles at these two seasons.

When the earths are prepared for delicate and precious works, such as porcelain or china, care must be taken to remove every thing which might alter the paste, and not to use any tools which might mix any prejudicial substance with it. The earth is purified by a very simple process: for this purpose, after having bruised it and diluted it in rain-water, it is put into a cylindrical cask three or four feet high; this cask has stop-cocks placed in its side, the one above, the other at the distance of about six inches, so that the lowest one is about two or three inches from the bottom. This cask is filled with diluted clay; the liquid paste is carefully stirred, and after settling for a few seconds, in order to allow the sand to precipitate, the upper stop-cock is turned in order to draw off all that is above it; the second is then opened, the third, and so on, until the whole of the liquid which holds the earth suspended in it is drawn off. The decanted liquor is put into vessels of baked clay; the clay suspended in it is allowed to precipitate; the water is decanted and the clay is collected, which is dried in the shade and out of the reach of dust. This clay, mixed in just proportions with calcined silex, pounded and ground, sometimes with bruised fragments of old earthen-ware, with baked and sifted gypsum and other substances, forms the composition of porcelain; and this composition is sifted several times through hair-sieves. The mixture is afterwards moistened with rain-water in order to form a paste, which is put into covered casks. This paste is called by the workmen the mass. A fermentation soon takes place, which changes its smell, colour and consistence. Sulphuretted hydrogen gas is formed; its colour passes from white to deep grey; and the matter is tougher and softer. The older this mass is the better it succeeds. It must be carefully moistened from time to time to prevent it from drying. The preparations of the mixture, and the art of rightly managing the mass are secrets in almost all manufactories. It is needless to repeat that the care taken in the preparation of the earths varies according to the work intended to be executed. In the potteries of coarse earthenware, the earth is put to soak in pits dug under the open air, and they are moistened with any kind of water. When it is wanted afterwards, the quantity is extracted from the pit which the occasion requires.

The second operation is to give the paste the form we wish, and this is done in three ways: 1st. by the labour of the hands; 2d. by means of moulds; 3d. by means of the lathe. The choice of one or other of these methods is not in the power of the artist; the nature of the works, their size and form, must determine the employment of this or that method. In every case where the paste is well prepared for working, a new perfection is given to it, by mixing it and kneading it with the hands, and even by beating it upon tables with large round pieces of wood: this is what is called dressing the earth. By these mechanical operations the earth is well divided, well mixed, and of an equal consistence.

It should be observed, that an intimate mixture of the ingredients used in pottery is of great importance to the beauty, compactness, and soundness of the ware. Formerly the wet clay and ground flint, or whatever else was employed, were beat together with long continued manual labour; but this expensive method has now been laid aside in the larger potteries, and they substitute for it another plan, which is that of bringing each material first to an impalpable powder, and diffusing them separately in as much water as will bring them to the consistence of thick cream, and when thoroughly mixed, the superfluous water is evaporated till the mass is brought to a proper consistence. In the potteries of Staffordshire the materials are a fine clay brought chiefly from Devonshire, and a siliceous stone named *cher*, or common flint reduced to powder by heating it red-hot, quenching it in water and then grinding it in mills. Each material is passed through very fine brass sieves, then diffused in water, and brought to a plastic state.

The works which are made with the hand are, 1st. all sculptures, which are afterwards baked in order to give them the convenient hardness; busts and other ornaments are of this description. 2nd. Good glass-house pots, for by this means the earth is better dressed than it can be by the lathe. The works done in the mould are tiles, bricks, &c. The mould, of wood or iron, is of the form proposed to be given to the piece: it is open at the two faces, so that it is, properly speaking, merely a frame for the purpose of giving equal dimensions to the various works we are doing. This frame is used on a table covered with a little sand or ashes, to prevent the adhesion of the paste: the frame is then filled with prepared clay; by the help of a cutting instrument, which we apply with both hands over the top of the mould, the excess of clay is taken off.

Almost all vessels of a cylindrical form, or which are hollow, are wrought with the lathe. The wheel and lathe are the chief and almost the only instruments made use of: the first for large works and the last for small. The potter's wheel consists principally in the nut, which is a beam or axis, whose foot or pivot plays perpendicularly on a free-stone sole or bottom. From the four corners of this beam, which does not exceed two feet in height, arise four iron bars called the spokes of the wheel; which, forming diagonal lines with the beam, descend, and are fastened at bottom to the edges of a strong wooden circle four feet in diameter, perfectly like the fellies of a coach-wheel, except that it has neither axis nor radii, and is only joined to the beam which serves it as an axis by the iron bars. The top of the nut is flat, of a circular figure, and a foot in diameter; and on this is laid the clay which is to be turned

turned and fashioned. The wheel thus disposed is encompassed with four sides of four different pieces of wood fastened on a wooden frame; the hind piece, which is that on which the workman sits, is made a little inclining towards the wheel; on the fore-piece is placed the prepared earth; on the side-piece he rests his feet, and these are made inclining, to give him more or less room. Having prepared the earth, the potter lays a round piece of it on the circular head of the nut, and sitting down, turns the wheel with his feet till it has got the proper velocity; then, wetting his hands with water, he presses his fist or his fingers-ends into the middle of the lump, and thus forms the cavity of the vessel, continuing to widen it from the middle; and thus turning the inside into form with one hand while he proportions the outside with the other. the wheel constantly turning all the while, and he wetting his hands from time to time. When the vessel is too thick, he uses a flat piece of iron, somewhat sharp on the edge, to pare off what is redundant; and when finished it is taken off from the circular head by a wire passed underneath the vessel.

The potter's lathe is also a kind of wheel, but more simple and slight than the former: its three chief members are an iron beam or axis three feet and a half high and two feet and a half diameter, placed horizontally at the top of the beam, and serving to form the vessel upon: and another large wooden wheel, all of a piece, three inches thick and two or three feet broad, fastened to the same beam at the bottom and parallel to the horizon. The beam or axis turns by a pivot at the bottom in an iron stand. The workman gives the motion to the lathe with his feet, by pushing the great wheel alternately with each foot, still giving it a greater or lesser degree of motion as his work requires. They work with the lathe with the same instruments and after the same manner as with the wheel. The mouldings are formed by holding a piece of wood or iron, cut in the form of the moulding, to the vessel while the wheel is turning round, but the feet and handles are made by themselves and set on with the hand; and if there be any sculpture in the work, it is usually done in wooden moulds, and stuck on piece by piece on the outside of the vessel.

Handles, spouts, &c. are afterwards fixed on to the moulded piece if required: and it is then set to dry for some days in a warm room, where it becomes so hard as to bear handling without altering its shape. When dry enough it is enclosed along with many others in baked clay cases of the shape of bandboxes, called seggars, which are made of the coarse clays of the country. These are next ranged in the kiln or furnace so as to fill it, except a space in the middle for the fuel. Here the ware is baked till it has remained fully red hot for a considerable time, which in the larger kilns consumes ten or fifteen tons of coals: after which the fire is allowed to go out, and when all is cooled the seggars are taken out and their contents unpacked.

The ware is now in a state of biscuit, perfectly void of gloss, and resembling a clean egg-shell. In order to glaze it, which is the next process, the biscuit ware is dipped in a tub containing a mixture of about sixty parts of litharge, ten of clay, and twenty of ground flint, diffused in water to a creamy consistence, and when taken out enough adheres to the piece to give an uniform glazing when again heated; for which purpose the pieces are repacked up in the seggars, with small bits of pottery interposed between each and fixed in the kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process for common white ware; though the painting and gilding require subsequent attention.

The process as described by M. Chaptal, to whose "Chemistry, as applied to the Arts," we are indebted for a part of this article, is somewhat different. The workman, he says, begins by moistening the paste and kneading it with the hands to give it the requisite softness. The workman afterwards takes the quantity he thinks necessary for his work. He sticks this piece of paste upon the middle of the horizontal wheel, to which he gives a rotatory motion, by pushing with his foot the lower wheel, parallel to and fixed on the same axis; and with his hands, which he applies forcibly to the paste, he shapes his work which he finishes by wooden tools applied to the sides of it while moving rapidly round, in consequence of the motion given to the wheel, so that the action of these mechanical agents is equal over all the points of the circumference; the workman then successively employs his hands and tools, until his work is finished. When it is wished to give a work the most perfect finishing possible, it is again carried to the lathe, when it has been dried a little, in order to render its forms more delicate and finished by means of various steel instruments well sharpened. Sometimes several of these processes are united in the execution of a single piece of workmanship. For instance, after having roughly given the principal forms the workman soaks the piece in water, and places it in a plaster mould; afterwards, by means of a wet sponge, with which he presses all the points of the surface, he fits his piece of ware to every part of the mould, and makes it assume the exact shape. The moulded figures are then withdrawn in order to dry them. The labour of the potter who makes figures is not so tedious, but it requires more address. The modeller, as well as the turner, has plaster moulds in which he casts the paste, and having left it some time in them in order to give it consistence, he extracts from it the moulded figures. But these figures very rarely come out whole, being moulded in pieces which are afterwards cemented together. They are then finished off with ivory tools, a pencil, and a sponge, after which they are dried.

A third operation, common to all potters, is baking, or firing: the construction of the furnaces varies according to the nature of the potteries; in general, they are round or square towers, the interiors of which present

sent two very distinct parts, separated by an arch pierced with several holes which give a passage to the flame. We may employ, almost indiscriminately, all kinds of combustibles in the firing of coarse earthen-ware; but, in general, that which gives most flame is preferred; and when we bake porcelain, we make use of very dry white wood alone, cut into small billets of an uniform size. The baking of porcelain and fine earthen-wares demands particular attention: we are obliged to enclose every separate piece in a case or frame, formed of a very porous taste, and which resists the action of heat; by this means we prevent the pieces baked from running or adhering to each other; and we also prevent any alteration which the smoke might produce in their colour. The firing of porcelain generally lasts from 36 to 48 hours. We judge of the state of the baking by proof-pieces, as they are called, placed in convenient situations, and which we can draw out and examine from time to time. It often happens, that the pieces of porcelain adhere to the sand which has been spread upon the bottom of their case or frame, in order to prevent immediate contact: the piece thus soiled, is applied to an iron wheel, upon which is placed emery bruised in water, and the half vitrified sand is thus completely removed. This is the reason why the bottoms of porcelain vessels are never covered with varnish on the place which rests upon the sand.

Of all the beautiful specimens of European porcelain which have been made in imitation of the oriental, it does not appear that any of them entirely unite the excellencies attaching to that manufactured in China and Japan. Earthy combinations have been made equally strong and infusible, and as truly porcelainous, or a substance of a perfect middle nature between pottery and glass, when burnt, but they have not quite rivalled the best Japanese, in delicate whiteness and lustre. To obtain these qualities, which have always been esteemed the most essential, that of infusibility has been frequently sacrificed: hence those that make a near approach to the oriental in beauty and delicate lustre, of which many manufactures in different parts of Europe have afforded capital examples, are frequently found to soften and melt down in an intense wind-furnace, at which the true Nankin or Japan china undergo no change whatever. Of British porcelain the curious will witness the finest specimens at the manufactory, at Derby.

There are some earthen-wares, which, after one baking, attain all the perfection they require: such as furnaces, crucibles, earths made into bricks, &c. But those productions of the pottery, intended to hold liquids, would be porous and ill suited to the end for which they are destined, if they were employed after a first firing. It is usual to cover the surface with a vitreous coating, which does not admit of water penetrating: it is this vitreous coating which is called varnish or glazing, in speaking of coarse or brown earthen-ware; enamel, in speaking of the white earthen-ware; covering, when the finest productions of the potteries, porcelain or china, are mentioned. The varnish of the coarse earthen-ware is made of lead: for this purpose the oxydes of lead are employed, such as minium or litharge, or rather the sulphuret of lead, which mineralogists call galena, and which is known in the language of commerce, and of the potteries, by the name of potters' ore. Whatever is the nature of the substance which forms the varnish, it is not employed until it is so well pounded that it remains some time suspended in water; and it is applied to the surface of the earthen-wares previously well dried, or by soaking them in water charged with it, when we wish to cover every part of their surface with varnish, or by throwing the same water upon such parts as we may wish to varnish separately and distinctly from the rest.

In the greatest number of establishments of the common kind of pottery in Paris, they begin by drying in the shade the pieces they wish to varnish; and when they have acquired the necessary degree of consistence, they are plunged into water which holds suspended in it a fat earth minutely divided, and previously passed through a silk sieve; the pieces are then hastily drawn out, covered by this operation by a slight coat of this earth. The colour of these earths forms the ground of the colour of the ware; and when a green colour is wanted, a little copper filings are added. Upon this coat of fat earth, a little dried, we may apply the sulphuret of lead, by projecting water charged with this mineral upon the ware: but it is almost every where mixed with equal parts of sand; the mixture of these two substances is pounded, so as to render it impalpable; it is soaked in water, and the piece of ware is covered with it where we wish to lay on the varnish. It is easy to see, that by this method we may vary and shade at pleasure the colour of the ware: it is only requisite to apply separately, upon the different parts of the surface, the fat, yellow, white, or red earths, and mixed or not with copper-filings. Some potters do not apply the varnish until the ware has undergone one firing; in this case they employ less varnish, as they only apply it to those pieces which have resisted the action of the fire; but the second firing which becomes necessary, requires more workmanship, consumes much more combustibles; and it is for the artist to calculate the advantages and disadvantages of these two methods. A black and vitreous colour may be given to earthen-ware, by throwing into the fire at the time of its greatest heat, some coal in powder or dust; the draught of the fire is consequently checked, so that it is filled with a thick smoke, which is deposited upon the ware, and forms a coat, which is vitrified as soon as the current of air re-kindles the fire. On throwing common sea-salt upon a well-heated fire, the salt is volatilized, and attaches itself in part to the softened surfaces of the earthen-ware, where it produces a commencement of vitrification. These two last methods are only applicable when the fire is very strong, and where the ware can undergo a sudden heat without flying or melting. It would be impossible to practice it however in our common potters' furnaces.

M. Chaptal endeavoured for a long time to find a substitute for the sulphuret of lead, by a varnish which should unite the same advantages, and be at the same time more economical. He first tried pounded glass; and obtained very satisfactory results from it. "I begin," he says, "first, by pounding with great care pieces of clear broken glass, and when I have reduced them to a very fine powder, I sprinkle with this powder the surface of the earthen-ware, covered with a weak coat of fat clay, according to the process above described. We may also mix this glass-powder with fat clay, dilute the whole in water, and plunge into it the dried pieces: this second process succeeds extremely well. This varnish covers well, it is not dangerous to use it, it is very economical, and does not require so much heat as the former. Since the year 1782, when I made it known, and executed it on a large scale, it has received some useful improvements in the potteries of Normandy, Languedoc, and Venaissin. I have also employed with success, volcanic products, which I treated in the same manner with the other varnishes. I transmitted in 1785, to the Comptroller-general of the Finances, a considerable number of bottles made of lava, and pieces of earthen-ware varnished with lava, that he might submit them to experiments, and have their quality ascertained: the results of these experiments were very favourable. M. Fourmy derived great advantage from this, by applying it to the manufacture of water-coolers, which he established at Paris." The enamel with which the earthen-ware called Delft, is covered, is merely glass, rendered opaque by the interposition of the oxyde of tin, which requires, in order to pass to vitrification, a greater degree of heat than the other substances which are mixed with it. Every artist has his own recipe and process for making his enamel, but all of them take lead and tin as their base, which they oxydate and mix in various proportions, with well-burnt sand. The composition which furnished Chaptal with the finest enamel was the following: he calcines with great care, equal parts of lead and tin: when the two metals pass to the state of oxyde, and present a fine powder only, they are carefully pounded and passed through the sieve: this powder is then boiled, and water is thrown upon it: after the deposit is formed, a fresh quantity of water is poured upon the deposit, in order to dilute it; he then decants the water, which holds in suspension the most minutely divided parts, and allows it to settle. The residue is pounded, sifted, and treated with water in the same manner; and by repeating this course of operations several times, the whole is brought to the same degree of fineness and tenuity: this powder is afterwards dried, in order to use it as occasion requires. On the other hand, he calcines very white flints, free from all foreign matter, and purifies them from the salt of tartar, so that there is only a carbonate of potash. These three substances being thus prepared, he weighs 100 parts of mixed oxydes of lead and tin, 100 parts of calcined flint, and 200 parts of carbonate of potash: all these are to be well mixed, and melted in a crucible. Merret has suggested the substitution of white oxyde of antimony for the oxyde of tin. Dauet also observed, that a fine enamel was obtained by melting white clay with gypsum. But these processes are not yet sufficiently confirmed by experiments, to entitle them to be adopted in the manufactories. The enamel of delft-ware, may be coloured by adding various metallic oxydes to the composition. The following are receipts given by M. Chaptal for the composition of the coloured enamels:—

1st. *Azure blue*. Three ounces of zaffre, and 60 grains of calcined copper, added to six pounds of the enamel composition.

2nd. *Turkish blue*. Six pounds of white enamel, three ounces of oxydated copper, 98 grains of zaffre, 48 grains of manganese.

3rd. *Green*. Six pounds of white enamel, three ounces of oxydated copper, 60 grains of iron-filings.

4th. *Shining black, or deep blue*. Six pounds of white enamel, three ounces of zaffre, three ounces of manganese.

5th. *Very brilliant black*. Six pounds of white enamel, six ounces of red tartar, and three ounces of manganese.

6th. *Purple*. Six pounds of white enamel, three ounces of manganese.

7th. *Yellow*. Six pounds of white enamel, three ounces of tartar, 72 grains of manganese.

8th. *Sea-green*. Six pounds of white enamel, three ounces of oxyde of copper, 60 grains of zaffre.

9th. *Violet*. Six pounds of white enamel, two ounces of manganese, 48 grains of oxyde of copper.

Whatever be the nature of the enamel, when we wish to apply it, it must be pounded and diluted in water, and we must throw this water which holds it in suspension, upon the vessels which have been already fired once; the water is absorbed into the texture of the ware, and the enamel powder remains on the surface. A second firing, stronger than the first, must be given to the ware, in order to melt the enamel. As it is material to preserve its fine white colour to the delft-ware, it must be fired in cases, in the same manner as porcelain. The earthen-ware of Mr. Wedgwood, having acquired great celebrity wherever it is known, under the appellation of English ware, or Wedgwood's ware, we shall describe the principal compositions which form the colours of this ware.

First Process, or Preparation of the Ingredients.—1. A white earth from Ayoree, in North America: calcine this in a red-heat about half an hour. 2. Bronze-powder. Dissolve one ounce of pure gold in aqua regia; precipitate it with copper; then wash the precipitate with hot water till it is sweet, or clean from the acid; dry it, and lay it up for use. 3. Take two ounces of crude antimony, levigated, two ounces of tin ashes, and six ounces of white-lead; mix them well together, and calcine them in a potter's furnace along with glass cream-coloured ware. 4. Take eight ounces of good smalt, one ounce of roasted borax, four

ounces

ounces of red-lead, and one ounce of nitre; mix the ingredients well together, and fire them in a crucible, in a potter's biscuit-oven. 5. Take English copperas, or vitriol of iron, calcine it in a moderate red-heat about two hours, then wash it in hot water till it is sweet; dry it and lay it up for use. 6. White-lead. 7. Flint, calcined and ground. 8. Manganese. 9. Zaffre. 10. Copper, calcined to blackness.

Second Process, or compounding and mixing the Colours.

Shining Black, A.—Three ounces of No. 8, above, three ounces of No. 9, three ounces of No. 10, eleven ounces of No. 6, and six ounces of the green, F, below.

Red, B.—Two ounces of No. 1, two ounces of No. 3, one ounce of No. 5, and three ounces of No. 6.

Orange, C.—Two ounces of No. 1, fourteen ounces of No. 3, half an ounce of No. 5, and four ounces of No. 6.

Dry Black, D.—One ounce of No. 4, and two ounces of No. 8.

White, E.—Two ounces of No. 1, and two ounces of No. 6.

Green, F.—One ounce of No. 1, two ounces of No. 3, and five ounces of No. 4.

Blue, G.—One ounce of No. 1, and five ounces of No. 4.

Yellow, H.—No. 3, alone.

Third Process, or Application of the Encaustic Bronze and Colours.—Application of the Bronze, I.—When the vessels are finished ready for burning, and before they are quite dry, grind some of the powder, No. 2, in oil of turpentine, and apply it to the vessels, or figures, with a sponge or pencil, to imitate bronze, in such a manner as your fancy directs: polish this powder upon the vessel or figure, and burn it, in such a furnace, and such a degree of heat, as is necessary for the ware; after it is burnt, burnish the bronze upon the vessel to what degree you please, and the process is finished.

Another Method of applying the Bronze after the Ware is fired Biscuit, as some Figures or Vessels may be too delicate to bear the Process I. K.—Take four ounces of No. 6, and one ounce of No. 7, grind them well together; spread this very thin, with a sponge or pencil, over the ware to be bronzed, and fire it till this layer of size is fluxed, which may be done in a potter's furnace; then take the powder, No. 2, and apply it to the vessel, as before directed; then burn the ware over again, till the powder adheres to the size: burnish, &c., as before.

Application of the Shining Black upon Red Vessels, in the Manner of the Antique Etruscan Vases, L.—Take the colour, A, grind it very fine with oil of turpentine, and with it trace the outlines of the design you intend to have upon the vessel; then fill up the vacant spaces very even, and shade the drapery, &c. Fire the vessels in a heat sufficient to flux the black, and they are finished.

Another Method to produce a different Effect with the same Colour, in the Manner of the Etruscans, M.—Paint the design with the black laid on as dead colouring, upon the red biscuit-ware, and cut up or finish the design with red and other colours; for which purpose the above-mentioned ones are prepared; they must also be ground in oil of turpentine, and burnt upon the vessels in a muffle, or enamel-kiln.

Another Method to produce, in a more expeditious Way, nearly the Effect of the Process L, N.—Take the red, B, or the orange, C, and lay in your design with it, as a dead colour, upon black biscuit vessels; and shade it with the black, D, with or without the addition of any of the other colours; firing them upon the vessels as before directed. The covering of porcelain is a vitreous and transparent matter, which must be applied exactly over all the points of the surface, and incorporated with the paste, without cracking or flying.

Count Milly, who, in his work upon porcelain, has made us acquainted with three compositions for the covering, makes them consist of the same materials, varying the proportions only.

	First Compos.	Second Compos.	Third Compos.
Very white quartz	8 parts	17 parts	11 parts
White enamel	15	16	18
Calcined crystals of gypsum	9	7	12

Pure and colourless substances alone must be used for the covering. Feldspar is also made use of. Whatever be the composition, we must grind, with the greatest care, the substances which enter into it; their powder must be diluted in water, and a paste formed with it, which must be macerated in water like the mass of the porcelain. When we use it, it must be diluted in water, so as to give it a tolerable liquidity; and we must plunge in this liquid the porcelain which has already undergone the first firing. Figures, and generally all porcelain articles which are neither to be painted nor exposed to water, have no occasion for any covering; they are then sold in the state of biscuit. When the biscuit has received its covering, it constitutes white porcelain; and in this state it may be applied to every purpose. Hitherto we have only considered earthen-ware in respect to its utility; but art has so perfected this valuable branch of our industry, that we have succeeded in executing, in earthen-ware, the most complicated designs, with astonishing elegance and precision. "There is no one," says M. Chaptal, "who does not admire the beauty of form, the correctness of design, and brilliancy of colouring, in the porcelains of Sevres, and those of Messrs. Dilk and Guerrard." Among these prodigies of French industry, some parts of them belong to the art of design, and some to chemistry; with the latter branch, in particular, we are now occupied. The application of colours upon porcelain presents to us some very interesting points of view: on the one hand, the nature and choice of the colours; on the other, the art of applying and incorporating them. The colours are all derived from the metallic

metallic oxydes; these alone retain sufficient fixity to prevent the fire from destroying them. Nay, the metallic colours, although dull, in general, when applied, acquire lustre when they are subjected to the action of the fire. The colours are incorporated with a flux, which varies in the different manufactories. The following composition is generally adopted:—

	Drachms.	Grains.
Glass, in powder, free from lead,	4 .	0
Calcined borax, ...	2 .	12
Purified nitre, ...	4 .	24

These substances are carefully mixed and divided, and then vitrified in a crucible. This glass is afterwards ground, and incorporated with the colour. Gum, or oil of lavender, is used as a vehicle, when we wish to lay it on the biscuit. For this purpose, a pencil is used, and all the methods known in painting. Oxyde of gold, called precipitate of Cassius, makes purple colour. Gold, precipitated by tin and silver, produces violet colour. Copper, precipitated from its solutions in the acids by the alkalis, furnishes us with a fine green. The saffron of Mars and colchotar produce the reds. Zaffre makes blue. Diaphoretic antimony, mixed with glass of lead, forms the yellow. The browns and blacks are made with iron-filings and strong doses of zaffre. The oxyde of chrome forms a fine green. M. Brongniart, director-general of the porcelain manufactory at Sevres, has already attained several very important improvements in this branch of industry; and the manufacture of porcelain may expect great progress from the zeal and intelligence of this experienced naturalist.

PRINTING.

MUCH has been written on the history of this art; as, however, our limits do not allow us to enter at large on the subject, we shall briefly extract a paragraph or two from Dr. Thomson's excellent History of the Royal Society, to which we gladly refer our readers for a great deal of valuable information, and many curious and valuable articles on almost all kinds of scientific subjects.

Printing was discovered at Haarlem, in Holland, by Coster, and the first book was printed in the year 1430. It was a Dutch piece of theology, printed only on one side of the page, and in imitation of manuscript. The first attempts at printing were upon loose leaves, and the printed part was accompanied with cuts, somewhat in the manner of our present ballads. Coster's method was to cut out the letters upon a wooden block. He took for an apprentice John Fust, or Faustus, and bound him to secrecy. But Fust ran away with his master's materials, and set up for himself at Mentz. He had a servant called Peter Schoeffer, who first invented separate metal types. Fust, upon seeing them was so delighted, that he gave him, Schoeffer, his daughter in marriage, and made him his partner. The first book they printed is said to have been Cicero de Officiis, which bears the date of 1495. But other books are mentioned with earlier dates, 1457, 1442. They printed a number of Bibles, in imitation of manuscript, and Fust carried them to Paris for sale. The Parisians, upon comparing together the different copies, were confounded at the exact similarity they bore to each other in every part, a similarity so great, that the most exact copyist could not have attained it. They accused Fust of being possessed of some diabolical art. This at once obliged him to discover the secret; and gave origin to the story of Dr. Faustus.

After the discovery of the art of printing, thus brought about at Paris, it quickly made its way over the whole of Europe. The first book printed in England is said to have been Rufinus on the Creed: printed at Oxford, in 1468.

At first, the impression was taken off with a list, coiled up, as the card-makers use at this day. But when they came to use single types, they employed stronger paper, with vellum and parchment. At last, the press was introduced, and brought gradually to its present state. The same observation applies to the ink. At first, the common writing-ink was employed, and the printing-ink, of lamp-black and oil, at present used, was introduced by degrees. Rolling-press printing was not used in England till the time of King James the First; and then it was brought from Antwerp by the industrious John Speed.

The workmen employed in this art are compositors and pressmen. The first are those whose business it is to range and dispose the letters into words, lines, pages, &c. The pressmen are those who, properly speaking, are the printers, as they take off the impressions from the letters after they are prepared for that purpose by the compositors. The types being provided for the compositor, he distributes each kind by itself into small

cells or boxes made in two wooden frames called cases; the upper-case and the lower-case. The cells in the upper-case are ninety-eight in number: those of the lower-case are fifty-four.

The upper-case contains two alphabets of capitals, large and small capitals. They also contain cells for the figures, the accented letters, the characters used in references to notes, &c.; and one cell, the middle one in the bottom row, for the small letter k. The capitals in this case are disposed alphabetically.

The lower-case is appropriated to the small letters, the double letters, the points, parentheses, spaces, and quadrats. The boxes of the lower-case are of different sizes, the largest being for the letters most in use: but the arrangement is not, in this instance, alphabetical, the letters oftenest wanted being placed nearest to the compositor's hand. As there is no guide on the outside of the boxes to denote the letters which they respectively contain, it is curious to observe the dexterity manifested by the compositor in taking up the letters as he wants them from the different cells. Each case is placed in an inclined direction, that the compositor may reach the upper-case without any difficulty.

The instrument in which the letters are set is called a composing-stick; it consists of a long plate of brass or iron, on the side of which arises a ledge that runs the whole length of the plate, and serves to support the letters, the sides of which are to rest against it. Along this ledge is a row of holes for a screw intended to lengthen or shorten the line, by moving the sliders farther from or nearer to the shorter ledge at the end of the composing-stick. Where marginal notes are required, the sliding pieces are opened to a proper distance from each other. Before the compositor begins his work he puts a thin slip of brass plate, called a rule, cut to the length of the line, and of the same height as the letter in the composing-stick parallel with the ledge, against which the letters are intended to rest. Being thus furnished with an instrument suited to hold the letters as they are arranged into words, lines, &c., he places his copy on the upper-case before him, and holding the stick in his left hand, his thumb being over the slider, with the right he takes up the letters, spaces, &c. one by one, and places them against the rule, while he supports them with his left thumb, by pressing them against the slider, the other hand being constantly employed in setting in other letters. Having composed a line, he takes the brass rule from behind it, and places it before the letters of which it is composed, and proceeds to compose another line in the same way. But before he removes the brass rule he notices whether the line ends with a complete word, or with an entire syllable of a word, including the hyphen. If he finds that his words exactly fill the measure, he has nothing more to do with that line but proceeds with the next; but if he finds the measure not entirely filled at the ending of a word or syllable, he puts in more spaces, increasing the distances between the words until the measure is full; and this operation, which is called justifying, is done in order that all the lines in the composing-stick may be of equal length. Much depends upon exactness in justifying, and great care is taken by compositors that the lines are neither too closely wedged into the composing-stick, nor yet at all loose and uneven. The spaces are pieces of metal, of various thicknesses, exactly shaped like the shanks of the letters. They are used to regulate the distances between the words.

When the composing-stick has been filled with lines, being about ten or twelve, the compositor empties it on to a thin board called a galley, of an oblong shape with a ledge on two sides and a groove, to admit a false bottom. When the compositor has filled and emptied his stick he ties it up with a piece of pack-thread, and removes it from the galley either to the imposing stone or some other safe and convenient place. In this manner he proceeds until he has composed as many pages as are required to make a sheet, or, in some instances, a half-sheet. He then proceeds to arrange the pages on the imposing stone, which is a large oblong stone of five or six inches in thickness. The pages are to be so arranged that, when they are printed they may be folded to follow regularly. Great care is requisite in the imposing of a sheet or half-sheet, particularly of works in sizes less than folio or quarto.

Having laid down or disposed the pages in right order on the imposing-stone, the compositor proceeds to what is called dressing the chases. The chase is a rectangular iron frame of different dimensions, according to the size of the paper to be printed; having two cross pieces of the same metal, called a long and short cross, mortised at each end so that they may be taken out occasionally. By the different situations of these crosses the chase is fitted for different sized volumes, as folios, quartos, octavos, &c. To dress the chase, a set of furniture is necessary, consisting of small slips of wood of different dimensions. The first thing to be done, is to lay the chase over the pages; after this, that part of the furniture, called gutter-sticks, is placed between the respective pages. Then another part of the furniture, called reglets, is placed along the sides of the crosses of the chase. The reglets are of such a thickness as will give the book proper margin after it is bound. Having dressed the inside of the pages, the compositor proceeds to do the same with their outsides, by putting side-sticks and foot-sticks to them. Thus the pages being placed at proper distances, they are all untied, and fastened together by wooden wedges, called quoins. These wedges, being firmly driven up the sides and feet of the pages, by means of a mallet, and a piece of hard wood called a shooting-stick, all the letters are fastened together. The work in this condition is called a form, and is ready for the pressman, who lays it upon the press, for the purpose of pulling a proof. When this is done, the form or forms are rubbed over with a brush, dipped in lye, made of pearl-ash and water; they are then carefully taken off

the press, and the proof and forms delivered to the compositor's further care.

As it is impossible for the most careful compositor so to compose his sheets as that they shall not require to be carefully read and corrected before they are worked off, the next thing to be done is to put the proof, with the copy from which it has been composed, into the hands of the reader or corrector, whose business is to read over the whole proof two or three times with great care and attention, marking the errata in the margin of every page. The corrections are always placed against the line in which the faults are found. There are different characters used to denote different corrections: thus ‿ is put to signify that a word is divided that ought to be in one, as pe rson, instead of person; a mark resembling the Greek theta ϑ is put for dele, to intimate that something, as a point, letter, word, &c., dashed in that line, is to be taken out. If any thing is to be inserted, the place of insertion is marked with a caret, ‸, and the thing to be inserted written in the margin. Where a space is wanting between two words, or letters, that are intended to be separated, a parallel line must be drawn where the separation ought to be, and a mark somewhat resembling a flat in music # placed in the margin. An inverted letter or word, is noticed by making a dash under it, and a mark, nearly resembling the dele character reversed.

Mr. Stower, in his Printer's Grammar, observes, that marking turned letters tries a corrector's skill in knowing the true formation of them; without which, it would be better to mark them in the same manner as they do wrong letters, which is done by dashing out the wrong letter, and writing the proper one in the margin, unless they are very sure they can distinguish b, d, n, u, p, q, s, x, z, when they are turned, from the same letters with their nick the right way. Where a space rises up between two words, it is noticed by a + in the margin. When any thing is transposed it is denoted thus:

1	4	3	2
you	merit	your	mistake

for, "you mistake your merit;" and in the margin is added *tr.* for transposition. Where a new paragraph is required, a line in the shape of a crotchet [is made, and the same mark placed in the margin; also where a paragraph ought not to have been made, a line is drawn from the broken-off matter to the next paragraph; and in the margin is written *no break*. If italic letters are to be changed for roman, or vice versa, a line is drawn, thus ——, under the letters, and rom. or ital. is written in the margin. Where words have been struck out that are afterwards approved of, dots are marked under such words, and in the margin is written the word stet. Where the punctuation is required to be altered, the semicolon, colon, and period, are encircled in the margin. The comma and other points are marked as letters and words, viz. with a long oblique line immediately before them; which line is intended to separate the different corrections from each other that occur in the same line. When letters of a different fount or size are improperly introduced into the page, they are noticed by a small dash drawn through them, and the letters *w. f.* in the margin. There are some other marks used in correcting; such as √ for superior; where it is necessary to insert the apostrophe, the star, or other reference marks, and superior letters: cap. for capital; l. c. for lower-case, &c.

After a proof sheet has been read, and the errata noticed by the reader, it is again put into the hands of the compositor, who proceeds to correct in the metal what has been marked for correction in the proof. For this purpose he unlocks the form on the imposing stone, by loosening the quoins or wedges which bound the letters together. He then casts his eye over one page of the proof, noticing what letters, &c. are required. Having gathered as many corrections from the cases, between the thumb and fore-finger of the left hand, as he can conveniently hold, and an assortment of spaces, on a piece of paper, or in a small square box with partitions in it, he takes a sharp-pointed *steel bodkin* in his right hand. Placing the point of the bodkin at one end of the line, and the fore-finger of his left hand against the other, he raises the whole line sufficiently high to afford him a clear view of the spacing. He then changes the faulty letters or words, and alters his spaces before he drops the line.

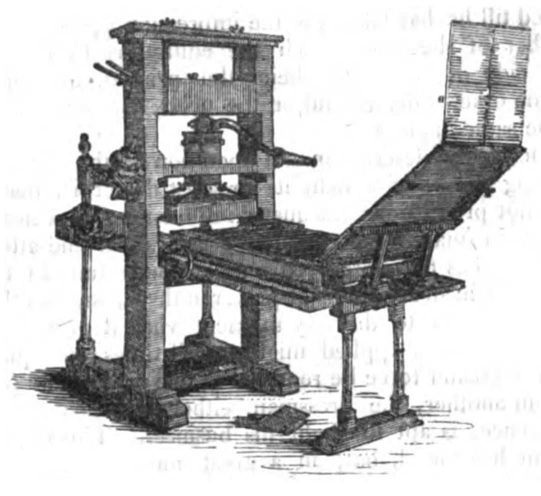
The first proof being corrected, another is *pulled*, to be put into the hands of the reader, or sent to the author for examination. This proof being read and corrected as before, a revise is pulled, to see whether all the errors marked in the last proof are properly corrected. When the sheet is correct, the forms are given to the pressman, whose business is to work them off when they are so prepared and corrected. Four things are now required; *paper, ink, balls,* and a *press*. The paper is prepared for use by being dipped, a few sheets at a time, in water, and afterwards laid in a heap over each other, to make the water penetrate equally into every sheet; a thick deal board is laid upon the heap, on which is placed heavy weights. The reason why the paper is to be wetted before it is in a fit state to be printed upon, is, that it may be made sufficiently soft to adhere closely to the surface of the letter, and take up a proper quantity of ink, that it may receive a clear impression. It is also necessary to wet the paper, lest its stiff and harsh nature, when dry, should injure the face of the letters.

The manufacture of good common ink seems to be as yet very imperfectly understood. That used in fine printing has been more attended to, and many of our printers are able to produce impressions in a great degree free from that offensive brown cast, which is to be observed in books printed with what is called common ink. The balls used in laying the ink on the forms are a kind of wooden funnels, with handles, the cavities of which are

are stuffed with wool or hair, and covered over with a pelt prepared for the purpose. One skin generally makes two proper sized balls. When the skin has been sufficiently soaked in urine, which will take about fourteen or fifteen hours, it is curried, by putting it round an iron called a currying iron, or round some upright post, the pressman taking hold of each end of it, and drawing it with as much force as possible backwards and forwards, till it is rendered soft and pliable. He then cuts the skin exactly in two, puts the pieces under his feet, and continues to tread on them till they are so dry as to stick to the foot in treading. The skin is then laid on a flat stone, and stretched as much as possible by rubbing the ball-stock upon it. It is then nailed upon the ball-stock in plaits about an inch wide, thrusting in as much wool as the cavity of the stock and the skin will conveniently hold. If, however, too much wool be put in, it will render the balls hard and difficult to work with. If too little wool is in the balls, they soon fall into wrinkles, so as to prevent an equal distribution of the ink on their surface. When the balls are thus knocked up, as it is termed, they are dipped in urine, and scraped with a blunt knife until they are perfectly clean; they are then dried with a clean sheet of stout paper, and patted with the hand until no moisture remains on the surface. The balls, when they are completed, have the shape and appearance of a large mallet, used by stone-masons, except that their surface is much broader and rounder.

The press is a curious and complex machine: it consists of two upright beams, called cheeks; they are generally about six feet one inch long, eight inches and a half broad, and five inches thick, with a tenon at each end. The tenon at the upper end of the cheek is cut across the breadth, and enters the cap within half an inch of the top. The cap is a piece of solid timber, three feet long, eleven inches wide, and four inches thick. The lower tenon of the cheek enters the feet, which is a square wooden frame made very thick and strong. The head, which is moveable, is sustained by two iron bolts that pass through the cap. The spindle is an upright piece of iron, pointed with steel, having a male screw which goes into the female one in the head about four inches. The spindle is so contrived, that when the pressman pulls a lever, which is attached to it, the pointed end of it works in a steel pan, or cup, supplied with oil, which is fixed to an iron plate let into the top of a broad thick piece of mahogany, with a perfectly plain surface, called a platten. This platten is made to rise and fall as the pressman pulls or lets go the lever or bar. When the platten falls, it presses upon a blanket, by which the paper is covered when it lies upon the form, from which the impression is intended to be taken. The form is laid upon a broad flat stone, or thick marble slab, which is let into a wooden frame, called the coffin, and which is made to move backwards or forwards, by the turning of a wince, or rounce. At the end of the coffin are three frames; two of which are called tympans, and the remaining one a frisket.

The following figure will afford a very good idea of this machine.



The tympans are square, and are made of three slips of very thin wood, and at the top a piece of iron, still thinner; that called the outer tympan is fastened with hinges to the coffin; they are both covered with parchment, and between the two are placed blankets, which are necessary to take off the impression of the letters upon the paper. The frisket is a square frame of thin iron, fastened with hinges to the tympan; it is covered with paper, cut in the necessary places, that the sheet, which is put between the frisket and the outer tympan, may receive the ink, and that nothing may hurt the margins. To regulate the margins, a sheet of paper is fastened upon this tympan, which is called the tympan-sheet, and which ought to be changed whenever it becomes wet with the paper to be printed upon. On each side is fixed an iron point which makes two holes in the sheet, which is to be placed on the same points when the impression is to be made on the other side. In preparing the press for working, or, as it is called by pressmen, making ready a form, great care and attention is requisite that the printed sheets may be in proper register, *i. e.* that the lines on one side may exactly fall upon the backs of the other. That the impression may be equable, the parchment which covers the outer tympan is wetted till it is very soft, the blankets are then put in, and secured from slipping by the outer tympan. When the form is made ready, and every thing is prepared for working, one man beats the letters with the ink-balls, another places a sheet of paper on the tympan-sheet, turns down the frisket upon it to keep the paper clean and prevent its slipping, then bringing the tympan upon the form, and turning the rounce, by which the carriage, holding the coffin, stone, and form, is moved, he brings the form with the stone, &c., under the platten; pulls with the bar, by which the

the platten presses the blankets and paper close upon the letter, whereby half the form is printed; then easing the bar, he draws the form still forward, gives a second pull, and letting go the bar, turns back the carriage, &c., raises the tympans and frisket, takes out the printed sheet and lays on a fresh one; and this is repeated till he has taken off the impression upon the full number of sheets of which the edition is to consist. One side of every sheet being thus printed, the form, for the other side, is laid on the press, and worked off in the same manner.

Such is the description and operation of the common printing press, of which, its greatest defect is, that it does not produce an adequate impression, from heavy works, in small letter, without great labour and attention. It has therefore been long a desideratum in the art to obtain an accession of power in the press, and that power adapted to the very moment when it is wanted, so that the force applied might, at all times, be equal: for if a greater force be required in one part of the pull than in another, the pressman, either from fatigue or negligence, is apt to slight his business. This object, so much wanted, has, in a great measure, been attained by the press invented by Earl Stanhope, of which the following may serve as a brief notice, rather than an accurate description; and those who would wish for a larger and fuller account we refer to Stower's Printer's Grammar, in which the several parts of the press are illustrated with wood cuts. To this work, indeed, we acknowledge our obligations for much of the present article. In the common press, the perfect plane in the table and platten, so long wished for, is completely obtained. Here the cheeks, the cap, and the winter, of the old press, are not required. In this press the platten is fixed to the apparatus through which the screw works; and it is suspended to the short arm by a lever, provided with a counterbalancing weight, by which the form is released from the platten, at the return after the pull. Instead of the stone is substituted a cast-iron block, which has its upper surface made accurately flat, and is laid correctly horizontal; this, with the provision made for a vertical pressure on the platten, and the care taken to bring its lower face parallel to the surface of the block ensures an uniform pressure on the form.

We may now notice an improvement in the common printing-press, by Mr. Joseph Ridley, to whom the Society of Arts, Manufactures, &c., in the Adelphi, voted a premium of forty guineas. In this press, the head is the chief object of improvement, from which the screw, hitherto in use, is taken away, and a perpendicular bar of steel, with a conical end lodged in a cup on the platten, substituted in its stead. The purchase is obtained by means of a spindle through each side of the press, near the bar, to which it is attached by three chains; the two outer ones serving to pull down the bar and platten, and the middle to raise or recover them again. To one end of this spindle is fixed a lever or handle, two feet long, which, by means of two chains pulls down the platten with any force required. At the other end of the spindle is also another lever, with a weight acting as a fly, which weight may be fixed by means of holes in the lever, at such a distance from the centre as may be judged necessary according to the nature of the work to be done. No work with this press requires more than one pull.

We now come to the *Stereotype* method of printing, to which the same presses are adapted as are required by the common mode. The mode of stereotype-printing is this: first, to set up a page, for instance, in the common way, and when it is rendered perfectly correct, a cast of plaster, hereafter described, is to be taken from it, in this cast the metal for the stereotype is to be poured. This method of printing, though not by any means a new invention, has been lately brought into practice by Earl Stanhope; but, as the subject has, of late years, caused some warm discussions, we must not pass it over.

The history of the invention of modern stereotype is, like that of common printing, involved in some obscurity as to the name of the person to whom justly belongs the honour of an invention so useful and curious. Mr. Andrew Tilloch, the editor of the Philosophical Magazine, has given the following extract, translated from a Dutch writer, which deserves to be noticed.

"Above a hundred years ago, the Dutch were in possession of the art of printing with solid or fixed types, which, in every respect, was superior to that of Didot's stereotype. It may, however, be readily comprehended that their letters were not cut in so elegant a manner, especially when we reflect on the progress which typography has made since that period. Samuel and J. Leuchtman, booksellers at Leyden, have still in their possession the forms of a quarto Bible, which were constructed in this ingenious manner. Many thousand impressions were thrown off, which are in every body's hand, and the letters are still good.

"The inventor of this useful art was J. Vander Mey, father of the well-known painter of that name. About the end of the sixteenth century he resided at Leyden. With the assistance of Muller, the clergyman of the German congregation there, who carefully superintended the correction, he prepared and cast the plates for the above-mentioned quarto Bible. This Bible he published also in folio, with large margins, ornamented with figures; the forms of which are still in the hands of Elive, bookseller, at Amsterdam: also an English New Testament, and Schaaf's Syriac Dictionary, the forms of which were melted down. Likewise a small Greek Testament, in 18mo.

"As far as is known, Vander Mey printed nothing else in this manner; and the art of preparing solid blocks was lost at his death; or, at least, was not afterwards employed." The Dutch editor supposes that the reason Vander Mey's invention was dropped, was, that "though this process in itself is very advantageous, it is far more expensive than the usual method of printing,

printing, except in those cases were such works are to be printed as are indispensably necessary, and of standing worth. Mr. Tilloch, however, is of a directly contrary opinion."

In the year 1781, was printed, by and for J. Nichols, London, a very interesting pamphlet, entitled Biographical Memoirs of William Ged; including a particular account of his progress in the art of block-printing. The first part of the pamphlet was printed from a MS., dictated by Ged some time before his death; the second part was written by his daughter, for whose benefit the profits of the publication were intended; the third is a copy of proposals that had been published by Mr. Ged's son, in 1751, for reviving his father's art; and to the whole is added Mr. More's Narrative of Block Printing.

It appears, from this publication, that, in the year 1725, Mr. Ged began to prosecute plate-printing. In 1727, he entered into a contract with a person who had a little capital, but who, on conversing with some printer, got so intimidated, that, at the end of two years, he had laid out only twenty-two pounds. In 1729, he entered into a contract with Mr. Fenner, Thomas James, a type-founder, and John James, an architect. Sometime after, a privilege was obtained from the University of Cambridge, to print Bibles and Prayer-Books; but it appears, that one of his partners was actually averse to the success of the plan, and engaged such people for the work as he thought most likely to spoil it. A straggling workman, who had wrought with them, informed Mr. Mores, that both Bibles and Common Prayer Books had been printed; but that the compositors, when they corrected one fault, made, purposely, half a dozen more; and the pressmen, when the masters were absent, battered the letter in aid of the compositors. In consequence of these base proceedings, the books were suppressed by authority, and the plates sent to the King's printing-house, and from thence to Mr. Caslon's foundry.

"After much ill-usage," says Mr. Tilloch, "Ged, who appears to have been a person of great honesty and simplicity, returned to Edinburgh. His friends were anxious that a specimen of his art should be published, which was at last done by subscription. His son, James Ged, who had been apprenticed to a printer, with the consent of his master, set up the forms in the night-time, when the other compositors were gone, for his father to cast the plates from; by which means Sallust, a copy of which we have seen, was finished in 1736." Mr. Tilloch has not only a copy of this work, but also a plate of one of the pages. Besides Sallust, Mr. Tilloch has another work, printed some years after from Mr. Ged's manufacture. The book is, The Life of God in the Soul of Man, printed on a writing pot, 12mo., and with the following imprint—"Newcastle, printed and sold by John White, from plates made by William Ged, Goldsmith in Edinburgh, 1742."

Fifty years after the invention of plate-printing by Mr. Ged, Mr. Tilloch made a similar discovery, without having, at the time, any knowledge of Ged's invention. In perfecting the invention, Mr. Tilloch had the assistance and joint labour of Mr. Foulis, printer to the University of Glasgow. After great labour, and many experiments, these gentlemen "overcame every difficulty, and were able to produce plates, the impressions from which could not be distinguished from those taken from the types from which they were cast." "Though we had reason to fear," says Mr. Tilloch, "from what we afterwards found Ged had met with, that our efforts would experience a similar opposition, from prejudice and ignorance, we persevered in our object for a considerable time, and, at last, resolved to take out patents for England and Scotland, to secure ourselves, for the usual term, the benefits of our invention." "Owing to circumstances of a private nature," not, however, connected with the stereotype art, the business was laid aside for a time; and Mr. Tilloch having removed from Glasgow to London, the concern was dropped altogether; not, however, till several small volumes had been stereotyped and printed, under the direction of Messrs. Tilloch and Foulis.

Some time elapsed after this, when Didot, the celebrated French printer, applied the stereotype art to logorithmic tables, and, afterwards, to several of the Latin classics, and to various French publications. It has been said, by the French, that the merit of the invention properly belongs to Didot; but, by what we have already laid before our readers, it is evident this cannot have been the case.

Some years after Mr. Tilloch had given up the prosecution of this art, Mr. Wilson, a printer of respectability in London, engaged with Earl Stanhope, for the purpose of bringing it to perfection, and eventually to establish it in this country. His Lordship, it is said, received his instructions from Mr. Tilloch, and had afterwards the personal attendance of Mr. Foulis, for many months, at his seat at Chevening, where his lordship was initiated in the practical part of the operation, and, for which, we have been informed, he paid eight hundred pounds.

After two years' application, Mr. Wilson announced to the public, "that the genius and perseverance of Earl Stanhope," whom he styles the inventor, had overcome every difficulty; and that, accordingly, the various processes of the stereotype art had been so admirably contrived, combining the most beautiful simplicity with the most desirable economy, the *ne plus ultra* of perfection, with that of cheapness, as to yield the best encouragement to the public for looking forward to the happy period when an application of this valuable art to the manufacture of books would be the means of reducing the price of all standard works, at least thirty, and, in many cases, fifty per cent.

In January, 1804, the stereotype art (with the approbation of Lord Stanhope), was offered, by Mr. Wilson, to the University of Cambridge, for their adoption and use in the printing of Bibles, Testaments, and Prayer

 Books,

Books, upon certain terms and conditions, and, both at Cambridge and Oxford, Bibles, Testaments, &c., are now generally stereotyped. Some few school-books have also been printed by this method; but, at present, there seems no reason to believe that the method will come into general use. It will be sufficient for us, in this place, to state the practice as given by Mr. Brightley, and then mention the advantages and disadvantages of this method of printing, as detailed by Mr. Wilson, on the one side, and his opponents, on the other.

"The first object of attention," says Mr. Brightley, "in this department, is the form of the type most convenient for casting plates. In new founts the letter-founder should be directed to leave the body of the letter square from the foot to the shoulder; the leads and spaces corresponding in height with the shoulder of the letter; so that, when standing together in a page, the whole may form one solid mass, with no other cavities than what are formed by the face of the letter. The composition of which the moulds are to be made, when applied to such pages, having no interstices to enter, and being indented only by the face of the letter, may be easily separated: but if cavities be left in the page, the mould will unavoidably break, and injure the impression.

"The quadrates should be cast rather lower than the shoulder of the letter, about one-third of the depth of pica. Otherwise the plate, which corresponds with the page, will be inconvenient to work at press: for where the whites are considerable, and the quadrates nearly the height of the letter, it is difficult to prevent the fouling of the paper. But if the quadrates be cast lower, this inconvenience will be avoided; and the cavities formed by these quadrates being large and shallow, there will be little difficulty in separating the moulds from the pages. If the composition break in those cavities, which sometimes happens, it is of little consequence, as it does not affect the face of the letter; and the metal may be afterwards reduced where it stands up too high. As the thickness of the plate, however, must in some measure be regulated by the position of the quadrates, care should be taken not to have them sunk too low; or the plate, when cast, will have holes in the places where the quadrates stood.

"The chases and furniture will next be considered, and here very little alteration is required. Each compositor should be provided with four, five, or six small chases, according to the nature of his work, so as to lock up a quarto page, two octavos, or three or four smaller ones when wanted. The furniture should be nearly four-fifths the height of the letter, and cut to such lengths that the page or pages, when locked up, may leave openings at the four corners, large enough to admit a quotation. The form should be carefully examined before it be sent to the foundry, to prevent letter or furniture from standing up above their proper level. It is also necessary, after pulling the last proof, to have the letter thoroughly cleaned. For this purpose it should be well washed in lye, and afterwards rinsed in clean water. And if any dirt or ink still remain in the letter, it must be carefully taken out with a picker, or the moulds will be defective wherever the dirt adheres."

We come next to the foundry in which the stereotype plates are cast. A room of sixteen or eighteen feet square will be sufficient to cast as many pages as can be set by fifteen or twenty compositors. It should be well ventilated, to prevent the fumes of the metal from injuring the workmen. The articles of furniture are the following:

"A moulding table or bench, covered with a piece of horizontal marble, like an imposing-stone, about eighteen inches wide, and long enough to contain ten or a dozen small chases (according to the extent of the business), in order to form the moulds from the pages. Instead of one large piece of marble, the table may consist of as many small ones as the number of chases require: and, as it is easier to level a small piece of marble than a large one, the latter method may be preferred. Another common wood bench or table, to lay plates and tools upon, will be convenient, and may be placed wherever the workman pleases. Where any quantity of business is done, two cast-iron ovens will be required, each four or five feet long, eleven inches high, and sixteen inches broad. The bottom and sides, which bear the action of the fire, should be, at least, an inch thick; the upper part something less. Double doors should be hung at each end, meeting in the middle, and well fitted to exclude the air. An additional lid, or door of sheet-iron, to close the whole, will tend to confine the heat and save fuel. The ovens are to be fixed in the open chimney, separated by a thin brick partition, with a furnace under each, fitted up in the best manner, with Rumford doors, &c., that the fire be not wasted. As metal will occasionally fall into the oven, it may be made to run out at the front, by raising the back a little higher at the time of fixing it. If a vacancy be left between the chimney-piece and the front of the ovens, the steam and heat will be carried off without incommoding the room. Fourteen or fifteen feet of the opening of the chimney will be occupied by the ovens. In the remaining part should be fixed a plumber's pot of cast-iron, to melt and mix the metal as it may be wanted. A small one will contain eight or ten hundred weight, and be sufficient for a moderate business. Another small pot to contain a quantity of metal equal to a day's consumption, may be fixed in the recess before-mentioned. The flue of the furnace may be carried into the general chimney."

In speaking of the metal, made use of in the manufacture of the stereotype plates, we have the following proportions:

To one hundred weight of regulus of antimony, broken into small pieces, and thoroughly cleaned, are to be added from five to eight hundred weight of hard lead, according to the hardness of the metal required. The lead is to be melted over a slow fire, and cleaned of

of all scum or oxyde. When melted, the antimony is to be gradually thrown in and kept stirred till the whole is melted. To every hundred weight of lead may be added about two pounds of block-tin.

In casting these plates, there must of course be a mould first made to form the counter-part of the original type. Here a substance is required of so delicate a texture, when soft, as to be capable of receiving an impression of the finest lines; and when dry, it must be capable of bearing the action of melted metal. The qualities will be found in plaster of Paris or gypsum, of which that found in Nottinghamshire is said to be the best, called gypsum-in-the-rock. It soon spoils if purchased in a prepared state; the stereotype caster should be able to burn it himself, and in quantities as he wants it. Mr. Brightley gives the following rule:

"Provide a pan of thin sheet-iron, of the length and breadth of the oven, and about five or six inches deep. Break the plaster into small pieces, sufficient to fill the pan; and after the process of casting for the day be over, enclose it in the oven, and keep up the fire about an hour afterwards. The oven doors should not be quite closed, till the evaporation has subsided: then the fire may be permitted to burn itself out, and the plaster to remain there till the morning. It is then to be laid upon a stone or bench, and pounded very fine, so as to pass through a lawn, or fine wire sieve. To ascertain its quality, mix a small quantity of it quickly with as much water as will make it into a thin paste. If it be good and fit for use, in about ten minutes it will become hard and strong: if otherwise, it will remain soft and watery."

The chief defects in this composition are, 1. That it is liable to contract and warp when exposed to a very high degree of heat: 2. That it is extremely difficult to expel the air and moisture, which it rapidly absorbs and tenaciously retains. We have heard that the chief secret in the Stanhope composition is the peculiar method by which his Lordship extricates his composition from these defects, and which he does in the completest way possible. To get rid of them the following method is recommended by Mr. Brightley: dissolve a quantity of common whitening in clear water, so as to make it of the consistence of what is generally used in white-washing. Mix the plaster with this solution, and it will contract very little by heat; the air and moisture will be readily expelled, and the mould will not be so liable to crack as plaster alone.

In the practice of moulding, which is done page by page, a frame of cast iron must be prepared half an inch wider and longer than the pages locked up in the chases. The frame determines the thickness and strength of the mould, and requires to be an inch deep, with the lower side contracted about a quarter of an inch, to prevent the mould from dropping through. To this must be added four cubical pieces of metal like quotations, whose height should be exactly four-fifths of the height of the letter: for on the height of these depends the thickness of the stereotype-plate. The pages are now to be laid flat upon the moulding table, and the letter planed down to an even surface. To prevent the adhesion of the plaster, it will be necessary to oil the face of the page with a soft brush, taking care to remove with a sponge what is superfluous; for, if the oil be allowed to stand in the letter, it will prevent the composition from sinking in, and the face of the plate, when cast, will be filled with metal. All the pages laid upon the moulding table are to be prepared in the same manner. Take now a quantity of the white-wash into a wooden bowl, and add to it so much prepared plaster as will make it a thin paste: stir it quickly with a large iron spoon till it be reduced to an equal consistency: apply it to the face of the letter with a brush, similar to what painters use, so as to fill every cavity, and then pour on the remainder of the plaster to fill the frame. When it begins to harden, strike off the superfluous plaster down to the frame, with a metal rule, and the back of the mould will be smooth and regular. The mould will next require to be separated from the pages; then to be dried, and afterwards hardened in a furnace, for all which processes, and likewise for *casting* the plates, directions are amply given in Mr. Brightley's pamphlet on the subject, to which we refer our readers.

After the plate has been cast, a few small imperfections will frequently be discovered; the eye of the *e* for instance, or other similar letters, may have been filled with dirt: these defects must carefully be remedied by means of instruments called pickers. This part of the business is done by persons employed for the purpose, in a room called the *picking* room. The plate is now ready for the press, and may be laid on blocks, and fastened down with a slip of brass and screws. Imperfections may still be found to exist, for if the loaded plate, which in casting is laid on the back of the stereotype-plate, be not truly horizontal, if the frames containing the moulds be not so too, if any dirt or other small substance get between, or if the mould have been warped from heat, then the stereotype plates will be of unequal thickness, and when put to the press, cannot give an even and true impression. The following remedy has been adopted to prevent these defects.

"Solder four or five pieces of split lead to the back of the plate, towards each corner and the centre, with their ends a little curved. Lay the plate, with its face downwards, on a smooth horizontal piece of marble, and gently lock it up in a chase, so that four straight pieces of iron, the exact height of moveable types, may surround it in a hollow square, corresponding with the size of the page. Mix up a quantity of a Roman cement (manufactured by Messrs. Parker and Co. Bankside, London), to fill the square, and strike it off correctly level with the frame, as in brick-making; and it is obvious that the plate and cement together will form a solid page, like moveable type. When hardened, it may be imposed and worked in the same manner as in common printing; and, as the cement will continue firm, without being affected by moisture,

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it will be nearly as durable as the metal to which it is attached.

"One precaution on this head is necessary. If the front of the plate do not, in all points, touch the marble when laid upon it, the face will, of course, remain uneven; and the defect, which this process was intended to remove, still continues. Let seven or eight rods of iron, about two feet long, be fixed to a horizontal rod as a centre, each having a moveable point, and a weight suspended at the end to form a lever. When the cement is poured on the plate, immediately press into it, at the four corners and centre, or at other different places in a large page, small pieces of thin tile. The rods being brought down over the page, with their points resting on the tiles, will press it close to the stone in every part: and the cement, when hardened, will keep it horizontal. The levers are then removed and the superfluous cement is smoothly planed off. Screws, or any thing else that will form a pressure, on different parts of the plate, so as to keep the face flat to the stone, will equally answer the purpose."

"The advantages arising from an application of this invention to the manufacture of books, are not," says Mr. Wilson, "confined to any particular department of the printing business. In every department of expenditure they are as self-evident as profitable, and need only to be mentioned to be well understood. In the first place, the *wear of moveable types*, in stereotyping, does not exceed 5l. per cent. of the heavy expense incurred by the old method of printing.—2dly. The expenditure upon *composition* and *reading* is nearly the same by both methods, for a first edition: but this great expense must be *repeated* for *every* succeeding edition from moveable types; whereas, by the stereotype plan *it ceases for ever*.—3dly. The expense of *stereotype plates*, when I am employed to cast them, is not 20l. per cent. of that of moveable type pages.—4thly. The expenditure upon *paper* and *press-work* is the same by both methods; but it is not incurred at the same time. The old method requires an advance of capital for a consumption of four years; whereas, by stereotype, half a year's stock is more than sufficient. It follows, therefore, that 12½l. per cent. of the capital hitherto employed in paper and press-work is fully adequate to meet an equal extent of sale.—5thly. A fire proof room will hold stereotype plates of works, of which the dead stock in printed paper would require a warehouse twenty times the size; and thus *warehouse-rent* and *insurance* are saved; with the additional advantage, in case of accident by fire, that the stereotype plates may be instantly put to press, instead of going through the tedious operations of moveable type printing; and thus no loss will be sustained from the works being out of print.—6thly. In stereotype, every page of the most extensive work has a separate plate; all the pages, therefore, of the said work, must be equally new and beautiful. By the old method, the types of each sheet are distributed, and with them the succeeding sheets are composed; so that, although the first few sheets of a volume may be well printed, the last part of the same volume, in consequence of the types being in a gradual state of wear as the work proceeds, will appear to be executed in a very inferior manner.—7thly. The stereotype art possesses a *security* against *error*, which must stamp every work so printed with a superiority of character that no book from moveable types ever can attain. What an important consideration it is, that the inaccuracies of language, the incorrectness of orthography, the blunders in punctuation, and the accidental mistakes that are continually occurring in the printing of works by moveable types, and to which every new edition superadds its own particular share of error,—what a gratifying security it is, that all descriptions of error are not only completely cured by the stereotype invention, but that the certainty of the stereotype plates remaining correct, may be almost as fully relied on as if the possibility of error did not at all exist!—If these observations be just with reference to the printing of English books, how forcibly must they be felt when applied to the other languages generally taught in this country!—how much more forcibly when applied to those languages which are the native dialects of the most ignorant classes throughout the United Kingdom, but which are as little understood as they are generally spoken!—8thly. Stereotype plates admit of alteration; and it will be found that they will yield at least twice the number of impressions that moveable types are capable of producing.—Lastly, All the preceding advantages may be perpetuated, by the facility with which stereotype plates are cast from stereotype plates.

"Such is a general outline of the present state of the stereotype invention; and such are the obvious advantages arising from it to learning and to ignorance,—to every state and condition of civilized life. From the whole it results, that a saving of 25l. to 40l. per cent. will accrue to the public in the prices of all books of standard reputation and sale, which, I believe, are pretty accurately ascertained to comprehend THREE FOURTHS of all the *book* printing of England, Scotland, and Ireland. It is fair to conclude, therefore, that the sales, both at home and abroad, will be considerably increased, and that the duties on paper will be proportionally productive; so that the public will be benefited in a twofold way by a general adoption and encouragement of the stereotype art. With this view, I think the period is now arrived when I ought to announce to all the respectable classes before-mentioned, particularly to printers and booksellers, that I am fully prepared to enable them to participate in the advantages to be derived from the stereotype art, in any way that may be most conducive to their particular interests, either individually or collectively."

We shall now state the arguments generally advanced in opposition to the practice of this invention.

"In the first place, the expense of the composition of every page (it being imposed separately, and two proofs, at least, taken from it before it can be in a proper state to undergo the process of making a plate from

from it), must be considerably greater than in the common mode.

"Secondly. In a first edition the bookseller has not only to pay for the higher-priced composition, but must be at the great expense of the stereotyping, which, in metal, independent of the charge for workmanship, is equal in weight to one-fourth of the same work set up in moveable types.

"Thirdly. The printer in stereotype must use higher-priced presses than are now commonly used, and must consequently increase his charge per ream; for hitherto all stereotype works have been printed at the Stanhope press, and at these presses it has not been done at the *common price*.

"Fourthly. The shape and manner of the first edition *must* be continued, or the first expense must be again incurred; for no deviation as to plan or size can possibly take place, nor any advantage be reaped from the future improvements in the shape of types.

"Fifthly. The bookseller has, *at present*, the certainty, or nearly the certainty, of detecting, particularly in town, any unjust advantage which might be taken of him, in point of number, by those with whom he intrusts his works: that important security will be wholly done away by plate-printing. He must also be subject to the loss sustained by the damage of plates (a highly probable circumstance), together with fraud by the "*facility with which stereotype plates are cast from stereotype plates.*"

Copper-plate printing requires some notice: this, which is a distinct trade of itself, is done by a machine called the rolling-press, which may be divided into two parts the body and carriage, analogous in some respects to the other.

The body consists of two cheeks of different dimensions, ordinarily about four feet and a half high, a foot thick, and two and a half apart, joined at top and bottom by cross pieces. The cheeks are placed perpendicularly on a wooden stand or foot, horizontally placed, and sustaining the whole press. From the foot likewise rise four other perpendicular pieces, joined by other cross or horizontal ones, which may be considered as the carriage of the press, as serving to sustain a smooth, even plank, about four feet and a half long, two feet and a half broad, and an inch and a half thick; upon which the engraven plate is to be placed. Into the cheeks go two wooden cylinders or rollers, about six inches in diameter, borne up at each end by the cheeks, whose ends, which are lessened to about two inches diameter, and called *trunnions*, turn in the cheeks between two pieces of wood, in form of half-moons, lined with polished iron to facilitate the motion. The space in the half moons left vacant by the trunnion, is filled with paper, pasteboard, &c., that they may be raised and lowered at discretion; so as only to leave the space between them necessary for the passage of the plank charged with the plate, paper, and blankets. Lastly, to one of the trunnions of the upper roller is fastened a cross, consisting of two levers or pieces of wood traversing each other. The arms of this cross serve in lieu of the handle of the common press; giving a motion to the upper roller, and that to the under one; by which means the plank is protruded, or passed between them.

The practice of printing from copper-plates is nearly as follows. The workmen take a small quantity of the ink on a rubber made of linen rags, strongly bound about each other, and with this smear the whole face of the plate as it lies on a grate over a charcoal fire. The plate being sufficiently inked, they first wipe it over with a foul rag, then with the palm of their left hand, and then with that of the right; and to dry the hand and forward the wiping, they rub it from time to time in whitening. In wiping the plate perfectly clean, yet without taking the ink out of the engraving, the address of the workman consists. The plate thus prepared is laid on the plank of the press; over the plate is laid the paper, first well moistened, to receive the impression, and over the paper two or three folds of flannel. Things thus disposed, the arms of the cross are pulled, and by that means the plate with its furniture passed through between the rollers, which, pinching very strongly yet equally, press the moistened paper into the strokes of the engravings, whence it licks out the ink.

RECTIFICATION.

Rectification and Distillation; we have referred an explanation of these operations to one article; though in this country, particularly in the metropolis, from whence we write, and its neighbouring villages, they make two distinct trades. Rectification is in fact but a second distillation, in which substances are purified by their more volatile parts being raised by heat carefully managed. Sometimes indeed the rectifier

fier has recourse to a third and even a fourth distillation, when he wishes his spirits or goods, as they are technically called, to be very clean and pure.

Distillation scientifically considered may be regarded as a process of evaporation or volatization, performed in vessels adapted to condense and collect the substance volatilized. In this way of considering the matter, it would divide itself into three classes, according as the substance obtained is solid, fluid, or gasseous. Our business is with the fluid class, but we may previously, to entering upon it, observe that distillation, where the principal product is solid, is commonly known by the name of *sublimation*, thus Benzoin acid, or, as it is called in the shops, Flowers of Benzoin, is a product distilled from the Benzoin in the impure state. The distillation of gasses is confined almost entirely to the experimental chemist and philosopher.

The apparatus for the distillation of liquids must consist of at least two parts, viz. the boiler, or vessel in which the materials are heated, and the vessel communicating with it, in which the steam or vapour is condensed into a liquid. Distillation of liquids on a large scale is usually carried on in the still refrigeratory. The still for manufacturers, consists of a boiler fixed in masonry with a fire-place beneath it, of a head, or capital as it is called, which is a hollow globe fitting upon the boiler, and with its upper part drawn out into a curved pipe of decreasing diameter, which describes a complete arch, and terminates at the upper part of the serpentine or worm in which it fits. The latter is a long pipe with a regularly decreasing diameter, which is arranged in a spiral form in the middle of a large tub of cold water, by means of which the vapour is condensed and trickles down in a small regular stream from the lower end of the worm, where it emerges from the side of the tub. The boiler of the still is generally made of tinned copper as well as the lower part of the capital, but the arched termination of the latter as well as the whole worm are of pewter. The joining between the boiler and the capital requires to be luted with slips of blodded and well made paste. The line of the tube from the arch of the capital to the bottom of the worm should be an uniformly descending spiral to prevent any lodgment of the distilled liquor, and some nicety is required in large stills, to give the worm an exact degree of slope. The management of the fire is of great importance in all distillations, to avoid on the one hand boiling over or burning the ingredients by too great a heat, and on the other to keep up the fire sufficiently strong to afford an even, regular evaporation into the condensing part of the apparatus. When too much heat is used there is danger of the capital being blown off by the great expansive force of the vapour, which is too suddenly generated and cannot be condensed with sufficient rapidity, or else the liquor in the boiler rises up into the capital and flows over into the serpentine. The latter accident, as it may be called, is perceived by the liquor coming out at the bottom of the serpentine not in a clear uniform stream, but by gushes and starts with a guggling noise, and coloured or fouled. When the stream of distilled water flows evenly, and the boiling liquor is heard to simmer moderately within the still, the process will be known to go on properly.

The objects of distillation, considered as a trade, are chiefly spirituous liquors; and the distillation of compound spirits and simple water, or those waters that are impregnated with the essential oil of plants, is commonly called rectification.

The great object of the distiller ought to be to procure a spirit perfectly flavourless, which, it is admitted, is not an easy task. The materials for distillation that have in this country been used in large quantities are malt, molasses or treacle, and sugar. All these, but sugar the least, abound with an oily matter, which rising with the spirit, communicates a disagreeable flavour, from which it is with the utmost difficulty freed. Previously to the operation of distillation, those of brewing and fermentation are necessary, for which we refer to the article BREWING. Methods have been suggested, and we believe carried into practice, for reducing the brewing and fermentation to one operation, which are said to improve the spirit in quality and greatly augment it in quantity. *On this principle* the following recipe has been given for fermenting malt for distillation, in order to get its spirit. Take ten pounds of malt reduced to fine meal, and three pounds of common wheat-meal; add to these two gallons of water, and stir them well together, then add five gallons of water boiling hot, and stir the whole well together. Let the whole stand two hours and then stir it again, and when grown cold, add to it two ounces of solid yeast, and set it by loosely covered in a rather warm place to ferment. This is said to be the Dutch method of preparing what is technically called the wash for malt spirit, which commodiously reduces the two processes of brewing and fermentation to a single operation. In London and its neighbourhood the method is to draw and mash for spirits as they do for beer, except that instead of boiling the wort they *pump it into* coolers, and afterwards draw it into backs to be then fermented with yeast. Thus in the opinion of some persons conversant with the subject, they bestow twice as much labour as necessary, and lose a large quantity of their spirit by leaving the gross bottoms out of the still for fear of burning.

All simple spirits may be considered in their different states of low wines, proof spirit, and alcohol. The first contain only one-sixth of spirit to five-sixths of water. Proof spirits contain one-half of totally inflammable spirit; and alcohol, if very pure, consists wholly of spirit, without any admixture or adulteration.

Malt low-wines, which is the first state after distillation from the *wash* prepared in the usual way, are exceedingly nauseous, owing to the gross oil of the malt that abounds in it. When these are distilled gently and by a slow fire into proof spirits, they leave a considerable quantity of this fetid oil behind in the still with the phlegm, the liquor loses its milky colour, and

and is perfectly clear and bright. When proof spirit from malt is distilled over again to be brought into the state of alcohol, the utmost attention must be paid to the fire, or some of the oil will be forced over and injure the whole process. The use of the balneum mariæ, instead of the common still, though a much more tedious process, would effectually prevent this mischief, and give a purer spirit in one rectification than can be procured in many, according to the common methods.

Malt spirit, and indeed spirits from other substances, must be brought into the state of alcohol, before it is adapted to internal uses, after which it is said to be more fit for all the various internal uses than even French brandy, it being by this purification a more uniform, hungry, tasteless spirit, than any other spirits which are frequently esteemed much better. A quarter of malt, according to its goodness, and the season of the year, will afford from eight to fourteen gallons of alcohol. The malt distiller always gives his spirit a single rectification *per se* to purify it a little, and in this state, though certainly not at all adapted to internal uses, it is frequently and at once distilled into gin or other ordinary compound liquors for the common people, who in this country injure their health, and eventually destroy their constitutions by the free use of them. The Dutch never give it any farther rectification than this: they distil the *wash* into low wines, and then at once into full proof spirit, from which they manufacture their celebrated Holland's geneva, which they export to foreign countries. Malt spirit, in its unrectified state, is usually found to have the common *bubble* proof, which makes it a marketable commodity, and which is obtained by mixing with it a certain portion of the gross oil of the malt; this indeed gives the rectifier much trouble if he require a very fine and pure spirit, but in general he does not concern himself about this, but mixes it still stronger by alkaline salts, and disguises its taste by the addition of flavouring ingredients. The spirit loses in these processes the vinous character which it had when it came out of the hands of the malt-distiller, and is, in all respects inferior, except in the disguise of a mixed flavour. The alkaline salts used by the rectifier, destroying the natural vinosity of the spirit, it is necessary to add an extraneous acid to give it a new one, and this is frequently what is denominated in the shops "spiritus nitri dulcis," and the common method of applying it, is the mixing it to the taste with rectified spirit; and it is said to be this that gives the English malt spirit a flavour something like brandy, which flavour is, however, very apt to fly off, and accordingly experienced manufacturers recommend the addition of a proper quantity of Glauber's strong spirit of nitre, to the spirit in the still. By this means the liquor comes over impregnated with it, the acid is more intimately mixed and the flavour is retained. The action of the alkali is thus explained: there is a greater attraction or affinity between the alkaline salt and the water than between the water and the spirit, of course the salt combines with the water contained in the spirit, and sinks with it to the bottom.

One great object with distillers in this country is a method of imitating the foreign spirits, particularly brandy and Holland's gin, it may not therefore be amiss to describe the modes adopted in France for the distillation of spirits from their wines. As brandy is extracted from wines, and as these are very different according to the grapes from which they are made, we may expect that there would be, as experience tells us there really is, a considerable difference in the flavour of foreign brandies. Every soil and climate, every variety of grapes varies with regard to the quantity and quality of the spirit extracted from them. Some wines are proper for distillation, others not at all so. The wines manufactured in Languedoc and Provence afford a great deal of brandy by distillation: but those of Orleans and Blois afford still larger quantities, but the best and what are deemed the highest flavoured brandies, are those distilled from grapes that are produced in the territories of Cogniac and Andaye. Hence in every public house people are enticed by a notice that the best Cogniac brandy is to be had there, whereas they probably deal in none that is not manufactured in their own neighbourhood.

Every thing that relates to the distillation of wines may be confined or reduced to two principles: 1. To communicate an equal heat to all the parts of the mass of the liquid, and to apply to them all the heat which is disengaged by combustion.

2. To condense expeditiously and entirely all the vapours which arise.

The construction of the furnace produces the first effect.

The disposition of the grate throws the fire-place under the anterior half of the diameter of the boiler, so that this part receives the direct action of the heat of the fire-place; and as the current of air always tends to carry the flame and the heat towards the chimney, it strikes in its passage against the other part of the bottom of the boiler.

This same current then rushes into the spiral flue, and applies itself to the whole lateral surface of the boiler where it spends its heat; so that the liquid is enveloped with all the heat that is disengaged from the combustible.

The form of the boiler greatly facilitates the action of the fire. Exclusively of the advantages which have already been mentioned, the concavity of its bottom contributes to augment the effect of the heat by applying it to a larger surface.

To produce the second effect, or to condense expeditiously the vapours which pass into the worm, nothing more is necessary than to keep cold water around it. For this purpose fresh supplies of water are made to enter at the bottom of the worm, and the heated water is drawn off from the top.

When it is possible to have a constant current, the water

water always keeps at a cool temperature, and the spirit exhales scarcely any smell, because it is highly condensed.

The distillation of wines has recently received improvement, and such are the advantages of these new processes, that the old establishments are no longer able to maintain a competition with those which are formed on the modern principles. These processes are still kept secret by their authors; but they probably depend on the apparatus.

The new apparatus for distilling is a genuine Woulf's apparatus. It consists of a cauldron fixed in a furnace, and a series of circular boilers which communicate with each other by means of pipes. The apparatus is terminated by a worm.

Wine is put into the cauldron, and into all the intermediate vessels between it and the worm. The neck attached to the head of the cauldron plunges into the liquor in the first vessel to the depth of ten or twelve inches. From the empty part of this first vessel runs a pipe, which plunges into the liquor of the second vessel to the same depth as the first. From the second issues another pipe that is adapted to the worm, which is cooled by the process we have described. When the wine contained in the cauldron is heated, the vapours which rise from it pass over into the liquid in the first vessel, and communicate to it a sufficient degree of heat to disengage from it the spirit of wine. These vapours of spirit of wine pass into the liquid of the second vessel, and effect the volatilization of the alcohol which it contains. Thus one moderate fire occasions the ebullition of a prodigious quantity of wine, distributed in several vessels: and the condensation of this large mass of vapours, takes place, as usual, in the worm. You may obtain spirit of greater or less strength, and procure, at pleasure, any degree of spirituosity you wish, by taking the produce of the first receiver, or of the second, &c. If, instead of employing wine you put water into the cauldron, and wine into the other vessels, you obtain a milder and more pleasant spirit than when you put wine into it. There is scarcely any occasion to observe that the water in the cauldron must be increased as fast as it decreases by evaporation, unless you calculate and determine the quantity requisite to complete the evaporation of all the alcohol contained in the wine to be distilled. In the contrary case it is easy to replace, by a very simple contrivance, the portion of the liquid which evaporates from the cauldron, without suspending or retarding the distillation. This process is attended with the twofold advantage of considerably diminishing the expense of fuel, since it is applied only to a small vessel in proportion to the mass of liquid which is evaporated, and of extracting more spirit from a given quantity of wine, than by the ordinary apparatus.

The improvements successively made in the process of distillation have produced spirits infinitely more mild than those obtained by the old processes. The latter have an empyreumatic, or burnt taste, but the consumers, especially in the north of France, were so accustomed to it, that for some time they refused to drink the milder and more pleasant tasted spirits, so that the distillers were obliged to render them empyreumatic by the admixture of burnt spirits, in order to suit their taste. Wines furnish more or less spirit, according to their degree of spirituosity: a very generous wine yields one-third of its weight of spirit. In Languedoc the average produce is one-fourth; the wines of Bourdeaux yield one-fifth, and those of Burgundy not so much.

The spirit extracted from old is of better quality than that obtained from new wines. Saccharine wines furnish an excellent spirit. Sour wines yield a spirit of very bad quality, on account of the great quantity of malic acid, which is almost inseparable from them. By diluting the husks of pressed grapes with water, and proceeding to distillation, you obtain a further portion of spirit, but it is of bad quality.

In distilling for the purpose of extracting spirits, you continue the operation till no more spirit of wine passes over, or till the produce ceases to be inflammable.—The distiller forms a judgment of the degree of spirituosity of the liquor which is distilling, *by the number* and size of the bubbles produced by agitating the liquor, and by the longer or shorter time of their duration. For this purpose he either pours it from one glass to another, letting it fall from a considerable height, or he fills a long bottle two-thirds full, and stopping it with his thumb, he shakes and strikes it with force against the hollow of his hand to form bubbles.

Various methods for determining the strength of spirits have been successively tried and practised: but in the year 1772, Messrs. Poujet and Borie of Cette, turned their attention to this subject, and obtained results which have furnished commerce with a spirit-gauge of such accuracy, as not to produce the least error in the estimates which are daily made with it. After having made very nice experiments on the proportions of water and alcohol, and on the action of the temperature on the mixture, at every possible degree, they adapted the thermometer to the spirit-gauge, and transferred to a scale the comparative progress of the real spirituosity, together with the effects of the temperature, so that their spirit-gauge itself indicates the alterations made by the temperature. This instrument is now the only one employed in commerce in the south of France. The use of such an instrument is so necessary in commerce, that for more than fifteen years the dealers of the south purchased Spanish spirits, which varied in the degree of spirituosity, and took no further trouble than to raise or reduce them to the degree of commerce, merely by adding either spirit of wine or water, in order to obtain an advantageous sale.

The produce of the distillation of wine is called in France Hollands proof spirits. But if you again subject this spirit to distillation, you then obtain a more spirituous liquor, which is called three-fifths. In this

case

case three parts of the liquor, mixed with two parts of pure water, form five parts of spirits, Hollands-proof.

With the spirit-gauge of Messrs. Borie and Poujet, the different degrees of spirituosity are very easily ascertained by means of silver weights of various sizes: the heaviest is inscribed with the words, Hollands-proof, and the lightest three-sevenths. The other weights serve to mark the intermediate degrees between these two terms. Thus, if you screw to the end of the beam of the spirit-gauge the weight denoting Hollands-proof, and plunge it into three-fifths, the instrument will descend in the liquid below the degree marked on the scale Hollands-proof, but it returns to that point on the addition of two-fifths of water, so that three-fifths spirit is thus transformed into Hollands-proof spirit. If, on the contrary, you screw on the three-fifths weight, and plunge the spirit-gauge into Hollands-proof, it will rise in the liquor above the latter mark, and it may be easily carried down to that degree by the addition of alcohol, or spirit of wine. When spirits are distilled for the purpose of extracting alcohol, or spirit of wine, the balneum mariæ is generally employed. The heat is then more gentle and more equal, and the produce of the distillation of superior quality.

Alcohol, or spirit of wine diluted, is used as a beverage. It is the dissolvent of resins, and constitutes the basis of drying varnishes. Spirit of wine serves as a vehicle for the aromatic principle of plants, and is then called spirit of this or that plant. The apothecary likewise employs spirit of wine to dissolve resinous medicines. These dissolutions are denominated tinctures. It forms the base of almost all the different sorts of beverage called liquors. It is sweetened with sugar, or rendered aromatic with all kinds of substances of an agreeable taste or smell. Spirit of wine preserves vegetable and animal substances from fermentation or putrefaction. To this end it is used for preserving fruits, vegetables, and almost all the objects and preparations relating to the natural history of animals. All the liquors produced by the fermentation of saccharine substances, yield alcohol. But the quantity and quality vary according to the nature of the substances.

It is chiefly in consequence of the ascent of bodies of greater lixity with certain bodies of greater volatility that there is so much difficulty here of imitating the foreign vinous spirits of other countries, as, for example—French brandies, and West-India rums. All these are remarkable by the character of the essential oil that ascends with the spirit, and which gives it the peculiar flavour by which one spirit differs from another. Now we can obtain an essential oil from any of the vegetables that furnish these different spirits: but we cannot, as we have seen, readily obtain a spirit altogether tasteless, and destitute of some sort of essential oil still combining with it. Could we do this, we could manufacture to perfection an artificial Cogniac brandy or Jamaica rum; but, as we cannot wholly separate the inherent essential oil from the purest and most colourless and most insipid spirit we can obtain, when we add the essential oil with which we mean to flavour it, the union of the two oils gives us a different result, and betrays the artifice to those who are acquainted with the taste of the genuine material.

In order, then, to prepare the oil of wine, or of the grapes from which French brandies are distilled, which are generally the worst that the country affords; the best being selected for the process of wine itself, as yielding a far ampler profit; take some cakes of dry wine-lees, dissolve them in six or eight times their weight of water, distil the liquor with a slow fire, and separate the oil, reserving, for only the nicest uses, that which comes over first, the succeeding oil being coarser and more resinous. Having procured this fine oil of wine, it may be dissolved in alcohol; by which means it may be preserved a long time, fully possessed of all its flavour, but, otherwise, it will soon grow rancid.

With a fine essential oil of wine, thus procured, and a pure and tasteless spirit, French brandies may be imitated to some degree of perfection. The essential oil, it should be observed, must be drawn from the same kind of lees as the brandy to be imitated was procured from; that is, in order to imitate Cogniac brandy, it will be necessary to distil the essential oil from Cogniac lees; and the same for any other kind of brandy. For as different brandies have different flavours, and as these flavours are entirely owing to the essential oil of the grape, it would be ridiculous to endeavour to imitate the flavour of Cogniac brandy with an essential oil procured from the lees of Bourdeaux wine. When the flavour of the brandy is well imitated, other difficulties are still behind. The flavour, though the essential part, is not the only one; the colour, the proof, and the softness, must also be regarded, before a spirit, that perfectly resembles brandy, can be procured. With regard to the proof, it may be easily accomplished, by using a spirit rectified above proof; which, after being intimately mixed with the essential oil of wine, may be let down to a proper standard with fair water; and the softness may, in a great measure, be obtained by distilling and rectifying the spirit with a gentle fire; and what is wanting of this criterion in the liquor when first made, will be supplied by time; for it is time alone that gives this property to French brandies, they being, at first, acrid, foul, and fiery. But with regard to the colour, a particular method is required to imitate it to perfection, which may be effected by means of treacle or burnt sugar.

The spirit distilled from molasses or treacle is tolerably pure. It is made from common treacle, dissolved in water, and fermented in the same manner as the wash for the common malt spirit. But if some particular art be not used in distilling this spirit, it will not prove so vinous as malt spirit, but less pungent and acrid, though otherwise much cleaner-tasted, as its essential oil is of a less offensive flavour. Therefore, if good fresh wine-lees, abounding in tartar, be well fermented with

with molasses, the spirit will acquire a greater vinosity and briskness, and approach nearer to the nature of foreign spirits. Where the molasses spirit is brought to the common proof-strength, if it be found not to have a sufficient vinosity, it will be very proper to add some dulcified spirit of nitre; and if the spirit be clean worked, it may, by this addition only, be made to pass for French brandy. Great quantities of this spirit are used in adulterating foreign brandy, rum, and arrack. Much of it is also used in making cherry-brandy, and other cordials, by infusion; but, in them all, many persons prefer it to foreign brandies. Molasses, like all other spirits, is entirely colourless when first extracted; but rectifiers always give it, as nearly as possible, the colour of foreign spirits.

In a similar manner we may imitate foreign spirits of all kinds. Thus, if Jamaica rum be our object, instead of French brandy, it will only be necessary to procure some of the tops of the sugar-canes, from which an essential oil being drawn and mixed with clear molasses spirit, will give it the real flavour; or, at least, a flavour as true as a spirit not totally divested of all essential flavour of its own can possibly communicate. The principal difficulty therefore must still lie in procuring a spirit totally, or nearly, free from all flavour of its own.

To rectify their spirit into Holland gin, the Dutch distillers add to every twenty gallons of spirit of the second extraction, about the strength of proof-spirit, three pounds of juniper-berries, and two ounces of oil of juniper, and distil with a slow fire, till the feints begin to ascend; then change the receiving-can. This produces the best Rotterdam gin. An inferior kind is made with a less proportion of berries, sweet fennel-seeds, and Strasburgh turpentine, without a drop of juniper-oil. This last is also a better sort, and though still inferior to that of Rotterdam, is produced in very large quantities at Welsoppe.

ROPE-MAKING

Is an art of very great importance, and there are few that better deserve the attention of the intelligent observer. Hardly any trade can be carried on without the assistance of the rope-maker. Cordage makes the very sinews and muscles of a ship; and every improvement which can be made in its preparation, either in respect to strength or pliableness, must be of immense service to the mariner, and to the commerce and defence of nations.

Rope-making has been defined the art of uniting animal or vegetable fibres into an aggregate line, so that the whole may concur in one joint action, and be employed under the forms of string, cord, cable, &c. Animal fibres, on account of their expense, are but seldom used, but those that are introduced into the employment are obtained either from the intestines or the hair. The intestines of sheep and lambs are manufactured into what is called *cat-gut*, of different sizes, for the use of musical-instrument-makers; for watchmakers, opticians, cutlers, turners, and a variety of other artificers. The tendrils of the ovary of the SQUALUS *canicula*, or dog-fish, are chiefly employed in angling, more frequently single than in the combined state, known in the trade by the name of *Indian-grass*. Animal hair, as that from horses, is had recourse to where there is no great friction, and it forms a rope or cord much more durable than any that can be obtained from vegetables: it is impervious to moisture, is capable of resisting all weathers, and is extremely elastic.

Hence, it is obvious, that the rope-maker must derive his chief material from the vegetable kingdom; which he does from the inner bark of the *hemp*, or CANNABIS *satira;* or from that of some of the species of flax, or LINUM; that of the L. *usitatissimum* is the most important. The treatment of both these plants being nearly the same, we shall describe, as nearly as we can, that relating to flax. The plant is rather common in most of the temperate parts of Europe, flowering in July. The root is annual, fibrous, and small; the stem is erect, round, smooth, and leafy; the flowers on stalks, erect, and of a sky-blue colour. About the end of August, when the flowers have attained their full growth, and begin to turn yellow at bottom, and brown at the top, and their seeds to ripen, it is a proper time to pull the plants up. They are dried, and threshed; they are then to be put in water till the bark readily separates from the stalk, when they are taken out and dried, after which they are in a proper state for the purpose of being converted into flax by the hackler. We may observe, though not strictly connected with the subject in hand, that, as from the bark of the stalks is manufactured flax or lint, for making of all sorts of linen cloth;—from cloth, when worn out, we make our paper;—from the seeds of the plant linseed oil is expressed; and, even the refuse, after the oil is

is extracted, forms oil-cakes, so valuable in fattening cattle, sheep, and other live stock. From hemp, however, treated in a similar way, we have the materials for cordage, ropes, and cables. Russian hemp is most used, but English hemp, when properly manufactured, is superior to that introduced from the North.

The aim of the rope-maker is to unite the strength of a great number of fibres, and the first part of his process is spinning of rope-yarns; that is, twisting the hemp in the first instance. This is done in various ways, and with different machinery, according to the nature of the intended cordage. We shall confine our description to the manufacture of the larger kinds, such as are used for the standing and running rigging of ships. An alley, or walk, is enclosed for the purpose, about two hundred fathoms long, and of a breadth suited to the extent of the manufacture. It is sometimes covered above. At the upper end of this rope-walk is set up the spinning-wheel. The band of the wheel goes over several rollers, called whirls, turning on pivots in brass holes. The pivots at one end come through the frame, and terminate in little hooks. The wheel, being turned by a winch, gives motion in one direction to all the whirls. The spinner has a bundle of dressed hemp round his waist, with the two ends meeting before him. The hemp is laid in this bundle in the same way that women spread the flax on the distaff. There is great variety in this; but the general aim is to lay the fibres in such a manner, that, as long as the bundle lasts, there may be an equal number of the ends at the extremity, and that a fibre may never offer itself double, or in a bight. The spinner draws out a proper number of fibres, twists them with his fingers, and having got a sufficient length detached, he fixes it to the hook of a whirl. The wheel is now turned, and the skein is twisted, becoming what is called rope-yarn, and the spinner walks backwards down the rope-walk. The part already twisted, draws along with it more fibres out of the bundle. The spinner aids this with his fingers, supplying hemp in due proportion, as he walks away from the wheel, and taking care that the fibres come in equally from both sides of his bundle, and that they enter always with their ends, and not by the middle, which would double them. He should also endeavour to enter every fibre at the heart of the yarn. This will cause all the fibres to mix equally in making it up, and will make the work smooth, because one end of each fibre is, by this means, buried among the rest, and the other end only lies outward; and this, in passing through the grasp of the spinner, who presses it tight with his thumb and palm, is also made to lie smooth. A good spinner endeavours always to supply the hemp in the form of a thin flat skein, with his left hand, while his right hand is employed in grasping firmly the yarn that is twining off, and in holding it tight from the whirl, that it may not run into loops or kinks. It is evident, that both the arrangement of the fibres, and the degree of twisting, depend on the skill and dexterity of the spinner, and that he must be instructed, not by a book, but by a master. The degree of twist depends on the rate of the wheel's motion, combined with the retrograde walk of the spinner. We may suppose him arrived at the lower end of the walk, or as far as is necessary for the intended length of his yarn. He calls out, and another spinner immediately detaches the yarn from the hook of the whirl, and gives it to another, who carries it aside to the reel; and this second spinner attaches his own hemp to the whirl-hook. In the mean time, the first spinner keeps fast hold of the end of his yarn; for the hemp, being dry, is very elastic, and if he were to let it go out of his hand, it would instantly untwist, and become little better than loose hemp. He waits, therefore, till he sees the reeler begin to turn the reel, and he goes slowly up the walk, keeping the yarn of an equal tightness all the way, till he arrives at the wheel, where he waits with his yarn in his hand till another spinner has finished his yarn. The first spinner takes it off the whirl-hook, joins it to his own, that it may follow it on the reel, and begins a new yarn. The second part of the process is the conversion of the yarns into what may, with propriety be called a rope, cord, or line. That we may have a clear conception of the principle which regulates this part of the process, we shall begin with the simplest possible case—the union of two yarns into one line.

When hemp has been split into very fine fibres by the hatchel, it becomes exceedingly soft and pliant, and after it has lain for some time in the form of fine yarn, it may be unreeled and thrown like flaxen yarn, so as to make sewing-thread. It is in this way, indeed, that the sail-makers' sewing-thread is manufactured, and when it has been kept on the reel, or on balls or bobbins, for some time, it retains its twist as well as its uses require. But this is by no means the case with yarns spun for great cordage. The hemp is so elastic, the number of fibres twisted together is so great, and the diameter of the yarn (which is a sort of lever on which the elasticity of the fibre exerts itself) is so considerable, that no keeping will make the fibres retain this constrained position.

The end of a rope-yarn being thrown loose, it will immediately untwist, and this with considerable force and speed. It would, therefore, be a fruitless attempt to twist two such yarns together; yet the ingenuity of man has contrived to make use of this very tendency to untwist not only to counteract itself, but even to produce another and a permanent twist, which requires force to undo it, and which will recover itself when this force is removed. Every person must recollect that when he has twisted a packthread very hard with his fingers between his two hands, if he slackens the thread by bringing his hands nearer together, the packthread will immediately curl up, running into loops or kinks, and will even twist itself into a neat and firm cord. The component parts of a rope are called strands, and the operation of uniting them with a permanent twist is called laying or closing, the latter term being chiefly appropriated to cables and other very large cordage.

The

The process for laying or closing large cordage is this: the strands of which the rope is composed consist of many yarns, and require a considerable degree of hardening. This cannot be done by a whirl driven by a wheel-band; it requires the power of a crank turned by the hand. The strands, when properly hardened, become very stiff, and when bent round the top, are not able to transmit force enough for laying the heavy and unpliant rope which forms beyond it. The elastic twist of the hardened strands must therefore be assisted by an external force. All this requires a different machinery and a different process. At the upper end of the walk is fixed up the tackle-board; this consists of a strong oaken plank, called a breast-board, having three or more holes in it and fitted with brass or iron plates. Into these are put iron cranks called heavers, which have hooks or forelocks, and keys on the ends of their spindles. They are placed at such a distance from each other, that the workmen do not interfere while turning them round. This breast-board is fixed to the top of strong posts, well secured by struts or braces facing the lower end of the walk. At the lower end is another breast-board fixed to the upright post of a sledge, which may be loaded with stones or other weights. Similar cranks are placed in the holes of this breast-board; the whole goes by the name of the sledge.

The top necessary for closing large cordage is too heavy to be held in the hand, it therefore has a long staff, which has a truck on the end. This rests on the ground, but even this is not enough in laying great cables. The top must be supported on a carriage, where it must lie very steady, and it needs attendance, because the master workman has sufficient employment in attending to the manner in which the strands close behind the top, and in helping them by various methods. The top is therefore fixed to the carriage by lashing its staff to the two upright posts. A piece of soft rope or strap is attached to the handle of the top by the middle, and its two ends are brought back and wrapped several times tight round the rope in the direction of its twist, and bound down. This greatly assists the laying of the rope by its friction, which both keeps the top from flying too far from the point of union of the strands and brings the strands more regularly into their places. The first operation is warping the yarns. At each end of the walk are frames called warping frames, which carry a great number of reels, or winches, filled with rope-yarn. The foreman of the walk takes off a yarn end from each, till he has made up the number necessary for his rope or strand, and bringing the ends together, he passes the whole through an iron ring fixed to the top of a stake driven into the ground, and draws them through; then a knot is tied on the end of the bundle, and a workman pulls it through this ring till the intended length is drawn off the reels. The end is made fast at the bottom of the walk, or at the sledge, and the foreman comes back along the skein of yarns, to see that none are hanging slacker than the rest. He takes up in his hand such as are slack and draws them tight, keeping them so till he reaches the upper end, where he cuts the yarns to a length, again adjusts their tightness, and joins them altogether in a knot, to which he fixes the hook of a tackle, the other block of which is fixed to a firm post, called the warping-post. The skein is well stretched by the tackle, and then separated into its different strands. Each of these is knotted apart at both ends. The knots at their upper ends are made fast to the hooks of the cranks in the tackle-board, and those at the lower ends are fastened to the cranks in the sledge. The sledge itself is kept in its place by a tackle, by which the strands are again stretched in their places and every thing adjusted, so that the sledge stands square on the walk, and then a proper weight is laid on it. The tackle is now cast off, and the cranks are turned at both ends in the contrary direction to the twist of the yarns (in some kinds of cordage the cranks are turned the same way with the spinning twist). By this the strands are twisted and hardened up, and as they contract by this operation the sledge is dragged up the walk. When the foreman thinks the strands sufficiently hardened, which he estimates by the motion of the sledge, he orders the heavers at the cranks to stop. The middle strand at the sledge is taken off from the crank; this crank is taken out, and a stronger one put in its place. The other strands are taken off from their cranks, and are all joined on the hook which is now in the middle hole; the top is then placed between the strands, and being pressed home to the point of their union, the carriage is placed under it, and it is firmly fixed down; some weight is taken off the sledge. The heavers now begin to turn at both ends; those at the tackle-board continue to turn as they did before, but the heavers at the sledge turn in the opposite direction to their former motion, so that the cranks at both ends are now turning one way. By the motion of the sledge-crank the top is forced away from the knot, and the rope begins to close. The heaving at the upper end restores to the strands the twist which they are constantly losing by the laying of the rope. The workmen judge of this by making a chalk mark on the intermediate points of the strands, where they lie on the stakes which are set up along the walk for their support. If the twist of the strands is diminished by the motion of closing they will lengthen, and the chalk mark will move away from the tackle-board; but if the twist increases by turning the cranks at the tackle-board, the strands will shorten and the mark will come nearer to it. As the closing of the rope advances the whole shortens, and the sledge is dragged up the walk. The top moves faster, and at last reaches the upper end of the walk, the rope being now laid.

In the mean time, the sledge has moved several fathoms from the place where it was when the laying began. These motions of the sledge and top must be exactly adjusted to each other. The rope must be of a certain length, therefore the sledge must stop at a certain place. At that moment the rope should be laid;

laid; that is, the top should be at the tackle-board. In this consists the address of the foreman. He has his attention directed both ways. He looks at the strands, and when he sees any of them hanging slacker between the stakes than the others, he calls to the heavers at the tackle-board to heave more upon that strand. He finds it more difficult to regulate the motion of the top. It requires a considerable force to keep it in the angle of the strands, and it is always disposed to start forward. To prevent or check this, some straps of soft rope are brought round the staff of the top, and then wrapped several times round the rope behind the top, and kept firmly down by a lanyard, or bandage. This both holds back the top, and greatly assists the laying of the rope, causing the strands to fall into their places, and keep close to each other, which is sometimes very difficult, especially in ropes composed of more than three strands. It will greatly improve the laying the rope, if the top has a sharp, smooth, tapering pin of hard wood, pointed at the end, projecting so far from the middle of its smaller end, that it gets in between the strands which are closing. This supports them, and makes their closing more gradual and regular. The top, its notches, the pin, and the warp, or strap, which is lapped round the rope, are all smeared with grease or soap to assist the closing. The foreman judges of the progress of closing chiefly by his acquaintance with the walk, knowing that when the sledge is a-breast of a certain stake, the top should be a-breast of a certain other stake. When he finds the top too far down the walk, he slackens the motion at the tackle-board, and makes the men turn briskly at the sledge. By this the top is forced up the walk, and the laying of the rope accelerates, while the sledge remains in the same place, because the strands are losing their twist, and are lengthening, while the closed rope is shortening. When, on the other hand, he thinks the top too far advanced, and fears that it will be at the head of the walk before the sledge has got to its proper place, he makes the men heave briskly on the strands, and the heavers at the sledge crank work softly. This quickens the motion of the sledge by shortening the strands; and by thus compensating what has been over-done, the sledge and top come to their places at once, and the work appears to answer the intention. When the top approaches the tackle-board, the heaving at the sledge could not cause the strands immediately behind the top to close well, without having previously produced an extravagant degree of twist in the intermediate rope. The effort of the crank must, therefore, be assisted by men stationed along the rope, each furnished with a tool called a woolder. This is a stout oaken stick, about three feet long, having a strap of soft rope-yarn, or cordage, fastened on its middle or end. The strap is wrapped round the laid rope, and the workman works with the stick as a lever, twisting the rope round in the direction of the crank's motion. The woolders should keep their eye on the men at the crank, and make their motion correspond with his. Thus they send forward the twist produced by the crank, without either increasing or diminishing it, in that part of the rope which lies between them and the sledge. Such is the general and essential process of rope-making. The fibres of hemp are twisted into yarns, that they may make a line of any length, and stick among each other with a force equal to their own cohesion. The yarns are made into cords of permanent twist by laying them; and that we may have a rope of any degree of strength, many yarns are united in one strand, for the same reason that many fibres were united in one yarn; and in the course of this process it is in our power to give the rope a solidity and hardness which make it less penetrable by water, which would rot it in a short while. Some of these purposes are inconsistent with others; and the skill of a rope-maker lies in making the best compensation, so that the rope may, on the whole, be the best in point of strength, pliancy, and duration, that the quantity of hemp in it can produce. The following rule for judging of the weight which a rope will bear is not far from the truth. It supposes them rather too strong; but it is so easily remembered, that it may be of use. Multiply the circumference in inches by itself, and take the fifth part of the product, it will express the tons which the rope will carry. Thus, if the rope has six inches circumference, 6 times 6 is 36, the fifth of which is $7\frac{1}{5}$ tons.

It is usual in cables, and in other cases, to have recourse to the operation of tarring. This is often done in the state of twine or yarn, as being the best mode by which the hemp can be uniformly penetrated. The yarn is made to wind off from one reel, and having passed through a vessel of liquid hot tar, is wound on another reel; the superfluous tar is taken off by passing through a hole surrounded with oakum: or, it is sometimes tarred in skeins, which are drawn by a capstern through a tar-kettle, and a hole formed by two plates of metal, held together by a lever, loaded with a weight. There is this peculiarity to be noticed—tarred cordage is weaker, when new, than white, and the difference increases by the keeping. From some very accurate experiments made more than half a century ago, it was found, that on newly-made cordage, the white was one-eighth stronger than that which was tarred, that, at the expiration of thirteen months, the difference in favour of the new was almost one-fourth: and, in about three years and a half, the difference was as 29 to 18. From these, and other experiments, it was ascertained, 1. That white cordage in continual service is one-third more durable than that which is subjected to the operation of tarring. 2. That it retains its strength much longer while kept in the warehouse. 3. That it resists the ordinary injuries of the weather one-fourth longer. It may then be asked, Why is tar ever used by the rope-maker? Because white cordage, when exposed to be alternately very wet and dry, is weaker than that which is tarred, and to this cables and ground-tackle are continually subjected. It has also been pretty well ascertained, that cordage which is only superficially tarred, is constantly stronger than that which is tarred throughout.

Before we conclude this article, we may notice Mr. Chapman's method of making ropes and cordage, for which he obtained, some years since, His Majesty's letters patent. The specification may be found in the ninth volume of the First Series of the Repertory, it it being too long to be admitted in our work: the following is, however, an outline of the whole:—

Rope-yarns are spun either by hand, or by machinery: in the practice of the first method rope-walks are necessary, and the fibres of the hemp are drawn into the yarn of different lengths proportionate in a given degree to their position on the outside or inside of the yarn; accordingly, when this yarn is strained and its diameter collapses, the inside fibres of hemp bear the greatest strain, and thus they break progressively from the inside.

In the spinning by a mill the fibres are all brought forward in a position parallel to each other, previously to their receiving their twist. They are consequently all of one length; and, when twisted, the outside fibres are most shortened by forming the same number of spirals round a greater axis than the interior, and thus they must consequently break the first, on the same principle that the outside yarns of strands of ropes manufactured in the old method break before the interior yarns; and consequently with less strain than ropes of the improved principle, where the strands (or immediate component parts of the rope) have been formed in such a manner as that all the yarns shall bear equally at the time of the rope's breaking.

Nevertheless, yarns spun by a mill have been found stronger than common yarns, on account of the great evenness with which they are spun; the manual labour in manufacturing is much less than in the common method: but on the other hand there is the expense of machinery, and the greater waste of hemp in preparing it for being drawn out in the progressive stages of its advance to the spindle.

The method invented by Mr. Chapman differs from both the preceding, in causing, by an easy and simple contrivance, the fibres of the hemp to be laid in the yarn in such a manner as the yarns themselves are laid in the strands of the rope manufactured on the new principle.

The machinery consists only of a spindle divided into two parts, the upper containing apparatus to draw forward the hemp from the spinner with twist sufficient to combine the fibres; which enables him to employ women, children, and invalids, and also to appropriate the rope-ground solely to the purpose of laying ropes.

The remaining parts of their invention consist chiefly in the giving from a stationary power internal motion to a loco-motive machine, viz. to the roper's sledge, on which the strands and the rope itself are twisted, by which contrivance they are enabled to apply a water-wheel or steam-engine to the whole process of making ropes of all kinds whatever.

Mr. Huddart likewise obtained a patent for an improved method of registering or forming strands in the machinery for manufacturing of cordage; which he effects in the following manner. 1. By keeping the yarns separate from each other, and drawing them from bobbins which revolve, to keep up the twist *whilst* the strand is forming. 2. By passing them through a register, which divides them by circular shells of holes; the number in each shell being agreeable to the distance from the centre of the strand, and the angle which the yarns make with a line parallel to it, and which gives them a proper position to enter. 3. A cylindrical tube which compresses the strand, and maintains a cylindrical figure to its surface. 4. A gauge to determine the angle which the yarns in the outside shall make with a line parallel to the centre of the strand when registering; and, according to the angle made by the yarns in this shell, the length of all the yarns in the strand will be determined. 5. By hardening up the strand, and thereby increasing the angle in the outside shell, which compensates for the stretching of the yarns and the compression of the strand.

SAWING.

This is a distinct business from the trades, in which, however, the saw is not only a very useful, but necessary implement, such as those of the carpenter, cabinet-maker, cooper, &c.

The saw is an instrument which serves to cut into pieces several solid matters; as wood, stone, ivory, &c. The best saws are of tempered steel, ground bright and smooth; those of iron are only hammer-hardened, hence, the first, besides their being stiffer, are likewise found smoother than the last. They are known to be well hammered by the stiff bending of the blade; and to be well and evenly ground, by their bending equally in a bow. The edge in which are the teeth is always thicker than the back, because the back is to follow the edge. The teeth are cut and sharpened with a triangular file, the blade of the saw being first fixed in a whetting-

whetting-block. After they have been filed, the teeth are set, that is, turned out of the right line, that they may make the kerf, or fissure, the wider, that the back may follow the better. The teeth are always set ranker for coarse cheap stuff than for hard and fine, because the ranker the teeth are set, the more stuff is lost in the kerf. The saws, by which marble and other stones are cut, have no teeth: these are generally very large, and are stretched out and held even by a frame.

The lapidaries, too, have their saw, as well as the workmen in mosaic; but of all mechanics, none have so many saws as the joiners: the chief are as follows.—

The *pit-saw*, which is a large two-handed saw, used to saw timber in pits; this is chiefly used by the sawyers.

The *whip-saw*, which is also two-handed, used in sawing such large pieces of stuff as the hand-saw will not easily reach.

The *hand-saw*, which is made for a single man's use, of which there are various kinds; as the bow, or frame saw, which is furnished with cheeks: by the twisted cords which pass from the upper parts of these cheeks, and the tongue in the middle of them, the upper ends are drawn closer together, and the lower set further apart.

The *tenon-saw*, which being very thin, has a back to keep it from bending.

The *compass-saw*, which is very small, and its teeth usually not set; its use is to cut a round, or any other compass-kerf: hence the edge is made broad, and the back thin, that it may have a compass to turn in.

The surgeons use a saw to cut off bones: this should be very small and light, in order to be managed with the greater ease and freedom, the blade exceedingly fine, and the teeth exquisitely sharpened, to make its way more gently, and yet with great expedition, in cutting off legs, arms, &c.

Saws are now generally used by butchers in separating the bones of the meat: the divisions by the saw are neater than those by the chopper, and there is a certain saving, as the chopper splinters bones, the parts of which cannot be included in the weight.

The *pit-saw*, is that which is chiefly used in the employment properly denominated sawing. The teeth are set rank for coarse work, so as to make a fissure of about a quarter of an inch. To perform the work, the timber is laid on a frame over an oblong pit, called the saw-pit; and it is cut by means of a long saw fastened in a frame, which is worked up and down by two men, the one standing on the wood to be cut, and the other in the pit. As they proceed in their work they drive wedges, at proper distances from the saw, to keep the fissure open, which enables the saw to move with freedom. This, though a profitable, is a very laborious employment, and hence have been introduced saw-mills, which, in different countries are worked by different means, as by men, by horses, by water, by wind, or by steam.

A *saw-mill*, worked by men, consists of several parallel saws, which are made to rise and fall perpendicularly by means of mechanical motion. In this case a very few hands are necessary to carry on the operation, to push forward the pieces of timber, which are either laid on rollers, or suspended by ropes, in proportion as the sawing advances. We shall, however, give a more detailed account of the saw-mills, as used in various parts of the world. The history of the invention of sawing is curious, and may be inserted.

In early periods of society, the trunks of trees were split with wedges, into as many, and as thin pieces as possible; and if it was necessary to have them still thinner, they were hewn, by some sharp instrument, on both sides, to the proper size. This simple but wasteful manner of making boards has been still continued in some places, to the present time. Peter the Great, of Russia, endeavoured to put a stop to it, by forbidding hewn deals to be transported on the river Neva. The wood-splitters perform their work more expeditiously than sawyers, and split timber is much stronger than that which has been sawn; for the fissure follows the grain of the wood, and leaves it whole; whereas the saw, which proceeds in the line chalked out for it, divides the fibres, and by these means lessens its cohesion and strength. Split timber, indeed, turns out often crooked and warped; but, in many purposes to which it is applied, this is by no means prejudicial; and the fault may, sometimes, be amended. As the fibres, however, retain their natural length and direction, thin boards, particularly, can be bent much better. This is a great advantage in making pipe-staves, and in forming various implements of the like kind.

Our common saw, which needs only to be guided by the hand of the workman, however simple it may be, was not known to the inhabitants of America when they were subdued by the Europeans. The inventor of this instrument has, by the Greeks, been inserted in their mythology, with a place among those whom they have honoured as the greatest benefactors of the earliest ages. By some, he is called Talus, and, by others, Perdix. Pliny ascribes the invention to Dædalus; but Hardouin, in the passage where he does so, reads Talus rather than Dædalus. Diodorus Siculus, Apollodorus, and others, name the inventor Talus. He was the son of Dædalus's sister; and was, by his mother, placed under the tuition of her brother, to be instructed in his art. Having, it is said, once found the jaw-bone of a snake, he employed it to cut through a small piece of wood; and, by these means, was induced to form a like instrument of iron, that is, a saw. This invention, which greatly facilitates labour, excited the envy of his master, and instigated him to put Talus to death privately. We are told, that, being asked, when he was burying the body, what he was depositing in the earth, he replied, "A serpent." This suspicious answer discovered the murder; and thus, adds the historian, a snake was the cause of the invention, of the murder, and of its being found out.

The saws of the Grecian carpenters had the same form,

form, and were made in the like ingenious manner as ours are at present. This is fully shewn, by a painting still preserved among the antiquities of Herculaneum. Two genii are represented at the end of a bench, which consists of a long table that rests upon two four-footed stools. The piece of wood which is to be sawn through is secured by cramps. The saw, with which the genii are at work, has a perfect resemblance to our frame-saw. It consists of a square frame, having, in the middle, a blade, the teeth of which stand perpendicularly to the plane of the frame. The piece of wood which is to be sawn extends beyond the end of the bench, and one of the workmen appears standing, and the other sitting on the ground. The arms, in which the blade is fastened, have the same form as that given to them at present. In the bench are seen holes, in which the cramps that hold the timber are struck. They are shaped like the figure 7; and the ends of them reach below the boards that form the top of it.

The most beneficial and ingenious improvement of this instrument was, without doubt, the invention of saw-mills; which are now generally driven either by steam, by water, or by the wind. Mills of the first kind were erected so early as the fourth century, in Germany, on the small river Roeur or Ruer, for though Ausonius speaks of water-mills for cutting stone, and not timber, it cannot be doubted that these were invented later than mills for cutting out deals, or that both kinds were erected at the same time. Pliny conjectures that the mill for cutting stone was invented in Caria; at least he knew no building incrusted with marble of greater antiquity than the palace of king Mausolus, at Halicarnassus. This edifice is celebrated by Vitruvius, for the beauty of its marble; and Pliny gives an account of the different kinds of sand used for cutting it; for it is the sand, he says, and not the saw, which produces that effect. The latter presses down the former, and rubs it against the marble; and the coarser the sand is, the longer will be the time required to polish the marble which has been cut by it. Notwithstanding these facts, there is no account in any of the Greek or Roman writers of a mill for sawing wood; and as the writers of modern times speak of saw-mills as new and uncommon, it would seem that the oldest construction of them has been lost, or that some important improvement has made them appear entirely new.

Becher says, that saw-mills were invented in the seventeenth century. In this he erred, for when settlers were conveyed to the island of Madeira, which was discovered in 1420, saw-mills were erected also, for the purpose of sawing, into planks, the various species of excellent timber with which the island abounded, and which were afterwards transported to Portugal. About the year 1427, the city of Breslau had a saw-mill, which produced a yearly rent of three marks; and, in 1490, the magistrates of Erfurt purchased a forest, in which they caused a saw-mill to be erected, and they rented another mill in the neighbourhood besides. Norway, which is covered with forests, had the first saw-mill about the year 1530. This mode of manufacturing timber was called the new art; and because the exportation of deals was by these means increased, that circumstance gave occasion to the deal-tithe, introduced by Christian III. in the year 1545. Soon after, the celebrated Henry Canzau caused the first mill of this kind to be built in Holstein. In 1552 there was a saw-mill at Joachimsthal, which, as we are told, belonged to Jacob Geusen, mathematician. In the year 1555 the bishop of Ely, ambassador from Mary queen of England to the court of Rome, having seen a saw-mill in the neighbourhood of Lyons, the writer of his travels thought it worthy of a particular description. In the sixteenth century, however, there were mills with different saw-blades, by which a plank could be cut into several deals at the same time. The first saw-mill was erected in Holland at Saardam, in the year 1596; and the invention of it is ascribed to Cornelius Cornelissen. Perhaps he was the first person who built a saw-mill at that place, which is a village of great trade, and has still a great many saw-mills, though the number of them is becoming daily less; for within the last thirty years a hundred have been given up. The first mill of this kind in Sweden was erected in the year 1653. At present, that kingdom possesses the largest perhaps ever constructed in Europe, where a water-wheel, twelve feet broad, drives at the same time seventy-two saws.

In England saw-mills had at first the same fate that printing had in Turkey, the ribbon-loom in the dominions of the church, and the crane at Strasburg. When attempts were made to introduce them, they were violently opposed, because it was apprehended that the sawyers would be deprived by them of their means of getting a subsistence. For this reason, it was found necessary to abandon a saw-mill erected by a Dutchman near London, in 1663; and in the year 1700, when one Houghton laid before the nation the advantages of such a mill, he expressed his apprehension that it might excite the rage of the populace. What he dreaded was actually the case in 1767 or 1768, when an opulent timber-merchant, by the desire and approbation of the Society of Arts, caused a saw-mill, driven by wind, to be erected at Limehouse, under the direction of James Hansfield, who had learned, in Holland and Norway, the art of constructing and managing machines of that kind. A mob assembled, and pulled the mill to pieces; but the damage was made good by the nation, and some of the rioters were punished. A new mill was afterwards erected, which was suffered to work without any molestation, and which gave occasion to the erection of others. It appears, however, that this was not the only mill of the kind then in Britain; for one driven also by wind had been built at Leith, in Scotland, some years before.

Saw-mills, as they are now constructed, are of two kinds, according as the saws employed effect their operation by a circular or by a reciprocating motion. Circular

cular saw-mills are the most simple in their construction. Mr. George Smart, at his manufactory for hollow masts, on the Surrey side of Westminster Bridge, has several of these. In one of the simplest, a wheel is turned by a horse, which gives motion to a pinion on a horizontal shaft; a spur-wheel is fixed on the shaft, and turns a pinion on another horizontal shaft, on which a wheel is fixed in the room above the machine, and the bearings for the gudgeons of the shaft are supported on the joists of the floor: by means of an endless strap passing round this wheel, and round a pulley on the spindle of the circular saw, a rapid motion is given to the saw: it is fixed on its spindle by a shoulder, against which it is held by another moveable shoulder pressed tight by a nut, on the end of the spindles which is tapped into a screw to receive it. The saw has a circular hole through the middle, fitting tight upon the spindle, so as to cause them to turn together.

The ends of the spindle are pointed, and that point nearest the saw works in a hole made in the end of a screw, screwed in a bench of stout planks, and well braced together; the other turns in a similar screw passed through a cross beam mortised between two vertical beams extending from the floor to the ceiling: one of the beams can be raised or lowered in its mortises by wedges put both above and below its tenons. In order to adjust the plane of the saw to the plane of the bench, there is a long parallel ruler, which can be set at any distance from the saw, and fixed by means of screws going through circular grooves cut through the bench. In using the machine, the ruler is to be set the proper distance from the saw of the piece of wood to be cut, and as the saw turns round, a workman slides the end of a piece of wood to it, keeping its edge against the guide or ruler, that it may cut straight. We have witnessed the operation, which is as neat as it is expeditious and ingenious.

When the saw requires sharpening, one of the screws at the end of its spindle must be turned back: the spindle and saw can be then removed, and may be fixed in a common vice to whet it, in the same manner as a common saw; the outsides of the teeth are not filed to leave a surface perpendicular to the plane of the saw, but inclined to it, and in the same direction that each tooth so filed is bent in the setting: by this means, the saw, when cutting, first takes away the wood at the two sides of the kerf, leaving a ridge in the middle of it, the use of which is to keep the saw steady in a right line, that it may not have a tendency to get out of the straight line in any place where the wood is harder at one side than on the other.

The most important machinery of this kind that we have seen is, unquestionably, at Portsmouth, for the manufacturing of ships' blocks; a full account of the machines is given in Dr. Rees's most valuable New Cyclopædia, to which we refer our readers, and from which we shall extract a brief description of one or two of the saws.

"*The great cross-cutting Saw.*—The tree subjected to the action of this machine is placed on a long frame or bench raised a little from the floor, and at the end of it is erected a frame, composed of vertical posts and cross timber, in the manner of a small and low door-way: through this frame the end of the tree is drawn by the capstan above-mentioned, its end projecting as much from the surface of the frame as is intended to be cut off; and it is fastened in the frame from rolling sideways, by a lever, which can be readily made to press upon it and hold it down. The saw itself is a straight blade, fixed into a wooden handle or pole at each end, to lengthen it: one of these handles is connected by a joint to the upper end of a lever, bent like an L, and having its centre beneath the floor: the horizontal arm of the lever is connected by a spear rod, with a crank on the end of a spindle near the ceiling of the room, the motion of which is regulated by a fly-wheel. By this means the saw has a reciprocating motion from right to left, nearly in a horizontal position, and exactly across the log it is to cut off, imitating in its motion the carpenter's hand-saw, considering his arm as the arm of the bent or L lever. The teeth of the saw are of course on the lower side of the blade, and are sloped so as to cut in drawing towards the lever. It rises and falls freely upon its joint at the end of the lever, and can be lifted up by the handle, at the opposite end of the blade, to take it off its work, which it follows up by its own weight. The machine being at rest, is prepared for work, by fixing the log in the frame as before mentioned, so that the surface of the frame intersects the log at the place where it is intended to be cross-cut. The saw, which was before lifted up by its handle, to be clear above the log, is now suffered to rest upon it, in the place where the cut is to be made; and to guide it at first setting in, the back of the saw is received in a saw kerf, made in the end of a piece of board, which is attached to the frame over the saw, but slides up and down in a groove to reach the saw at any height, according to the thickness of the log lying beneath it. Being thus prepared, the machine is put in action by a rope or strap which turns the fly-wheel and its crank. This giving a vibration to the bent or L lever, causes the saw to reciprocate horizontally across the tree, until it cuts it through: it follows up its cut by its own weight alone, but the attendant can at any time lift up the saw from its work, though its motion continues, by means of a rope which suspends the handle of the saw when required. As the saw gets into the tree it quits the guide above-mentioned, which becomes the less necessary as the saw goes deeper; a saw having no tendency to alter its first course, when cutting across the grain of the wood. We admire the simplicity of this machine, which nevertheless executes its work with much accuracy and expedition. It might be very usefully employed in many situations where great manual labour is spent in cross-cutting large logs of timber.

"*The cross-cutting circular Saw.*—This machine is for similar purposes, and stands close by the former. It is a circular saw, whose spindle is so mounted, as to move in any direction parallel to itself; the saw all the while continuing in the same plane, and revolving rapidly upon its axis, cuts the wood it is presented to, and as it admits of being applied at first on one side, and then on another side of the tree, a saw of moderate dimensions will be sufficient to divide larger trees, than could otherwise be done by it.

"*The great reciprocating saw for cutting up trees lengthwise.*—In this machine the saw works vertically: it has an horizontal carriage, on which the timber is fastened; this passes through a vertical frame with grooves, in which another frame slides up and down in the manner of a window-sash, and has the saw stretched in it. The saw-frame is moved up and down by means of a crank on an axis beneath the floor, which is turned by means of an endless rope. At every time the saw rises and falls, it turns a ratchet-wheel round, by means of a click, a few teeth; and this has on its axis a pinion, working a rack attached to the carriage of the tree, which by this means is advanced: at every stroke, the saw makes a proper quantity for another cut. The saw-frame is adapted to hold several saws parallel to each other, for sawing a tree into several boards at once, when required."

Saw-mills, for cutting blocks of stone, are generally moved horizontally. When a completely cylindrical pillar is to be cut out of one block of stone, the first thing will be to ascertain in the block the position of the axis of the cylinder: then lay the block so that such axis shall be parallel to the horizon, and let a cylindrical hole of from one to two inches diameter be bored entirely through it. Let an iron bar, whose diameter is rather less than that of this tube, be put through it, having just room to slide freely to and fro as occasion may require. Each end of this bar should terminate in a screw, on which a nut and frame may be fastened The nut-frame should carry three flat pieces of wood or iron, each having a slit running along its middle nearly from one end to the other, and a screw and handle must be adapted to each slit; by these means the frame-work at each end of the bar may readily be so adjusted as to form equal isosceles or equilateral triangles; the iron bar will connect two corresponding angles of these triangles, the saw to be used two other corresponding angles, and another bar of iron, or of wood, the two remaining angles, to give sufficient strength to the whole frame. This construction, it is obvious, will enable the workmen to place the saw at any proposed distance from the hole drilled through the middle of the block; and then, by giving the alternating motion to the saw-frame, the cylinder may at length be cut from the block, as required. This method was first pointed out in the collection of machines approved by the Paris academy.

If it were proposed to saw a conic frustrum from such a block, then let two frames of wood or iron be fixed to those parallel ends of the block which are intended to coincide with the bases of the frustum, circular grooves being previously cut in these frames to correspond with the circumferences of the two ends of the proposed frustum; the saw being worked in these grooves will manifestly cut the conic surface from the block. This is the contrivance of Sir George Wright.

The best method of drilling the hole through the middle of the proposed cylinder seems to be this:—On a carriage, running upon four low wheels, let two vertical pieces (each having a hole just large enough to admit the borer to play freely) be fixed two or three feet asunder, and so contrived, that the pieces and holes to receive the borer may, by screws, &c., be raised or lowered at pleasure, while the borer is prevented from sliding to and fro by shoulders upon its bar, which are larger than the holes in the vertical pieces, and which, as the borer revolves, press against those pieces. Let a part of the boring-bar between the two vertical pieces be square, and a grooved wheel with a square hole of a suitable size be placed upon this part of the bar; then the rotatory motion may be given to the bar by an endless band which shall pass over this grooved wheel and a wheel of a much larger diameter in the same plane, the latter wheel being turned by a winch handle in the usual way. As the boring proceeds, the carriage with the borer may be brought nearer and nearer the block, by levers and weights, in the same manner as is described under the article PIPE-MAKING.

SHOT-MAKING.

SHOT, a denomination given to all sorts of balls for fire-arms; those for cannon being of iron, and those for guns, pistols, &c. of lead. The manufacture of common fowling leading shot consists merely in causing the fused metal to fall in equal spherical drops into water. The lead is melted with the addition of a small proportion of arsenic, which, being reduced to a metallic state, by means of grease stirred in during the fusion,

fusion, renders it less fluid. An oblong shallow vessel of iron, perhaps, ten inches wide, fourteen long, and two and a half deep, called a card, whose bottom is pierced with holes proportionate to the intended size of the shot, is placed at the height of from one to three inches, over the surface of a tub of water, covered with a thin film of oil. The card is previously heated to the temperature of the metal, by immerging it in the caldron; and a stratum of soft dross or scoriæ, which is found on the surface of the fused alloy, is then placed on its perforated bottom, and being slightly pressed down with the ladle, forms a kind of filter, which partly chokes up the apertures, and prevents the metal from flowing through them in continuous streams. The fused metal is then poured by ladle-fulls into this vessel, and appears, notwithstanding, to run through it with considerable velocity; so that it seems difficult to believe that it falls in separate drops, till convinced by taking up a quantity of shot from the bottom of the water.

The shot thus made is not without considerable imperfections. The exterior coat of the lower part of the drop becoming suddenly fixed by the contact of the water, its superior portion, which is still liquid, as it also cools and contracts, necessarily pits, like the surface of metal in the channel of a mould, so that the greater part of the shot are somewhat hollow, and of an irregular form; consequently too light for the purpose to which they are destined, and liable to unequal resistance in their passage through the air. These defects are remedied in the patent-shot, the manufacture of which differs only from that of the preceding kind in the addition of a larger portion of arsenic, which varies according to the quality of the lead; in dropping it from such a height that it becomes solid before it enters the water, which is from forty to one hundred feet; and, in some subsequent operations, which are as follows:—It is first dried and sifted. It is then boarded, which consists in scattering it on several polished slabs or trays of hard wood, with rims, in the form of a II, except that the sides converge towards the lower part, to which a slight inclination and alternate motion in their own planes are given by boys employed in the manufacture. The shot, whose form is imperfect, are detected by the sluggishness of their motion, and remain behind, whilst the others roll off from the board. The last operation is the polishing; which is performed by agitating it with the addition of a very small quantity of black lead, not exceeding two spoonfuls to a ton, in an iron vessel, turning on an horizontal axis like a butter churn. It does not appear that any higher degree of perfection than that which is thus attained remains to be desired. The argentine brilliancy of the shot when newly made, the beautiful accuracy of its form, and the curious instance of inanimate tactics which it presents when scattered on a plate, render it even an agreeable object of contemplation.

Patent milled shot is thus made:—Sheets of lead, whose thickness corresponds with the size of the shot required, are cut into small pieces, or cubes, in the form of a die. A great quantity of these little cubes are put into a large hollow cylinder which is mounted horizontally and turned by a winch, when, by their friction against one another, they are rendered perfectly round and very smooth. There are other patent shot cast in moulds, in the same way as bullets are.

SLATING.

Slating is employed, in architecture, in sundry ways, the principal of which refers to the covering of the roofs of buildings, but such has been lately the perfection of working in slate, that it is now wrought and fitted into many useful utensils, as well as made up into balconies, chimney-pieces, casings to walls, skirtings, stair-cases, &c. &c.

The slate, principally in use in London, is brought from Wales, taken from out of quarries, which are worked on the Lord Penhryn's estate at Bangor, in Caernarvonshire, and it is from thence forwarded to all parts of the United Kingdom. There are also in use some other kinds of slate, the best sort of which is brought from Kendal, in Westmoreland, and is called *Westmoreland slate*. These slates are of a fine pale bluish-green colour, and are most esteemed of any by the architects. They are not of a large size, but they are of good substance, and well calculated to give a neat appearance to the roof on which they may be placed. The slate brought from Scotland is nearly similar in both size and quality to a slate from Wales, called *Ladies*, from which circumstance they are very little sought after.

The French slates were very much in use about seventy years since. They are small in size, most commonly not larger than the Welsh doubles, excessively thin, and, consequently, light; but thin composition has been found not to be well adapted to this climate,

climate, where there is an atmosphere containing an excess of moisture. By analysis, this slate is ascertained to contain $\frac{1}{30}$ of manganese, besides other matters, such as iron, &c., the excessive affinity of which for oxygen soon shivers the stony portion of the slate into atoms, when employed as a covering to buildings in this country. The writer of this article has seen slates of this kind on a roof reduced to the state of powder, having become so by exposure, and appeared to be completely decomposed.

Of the Pitch of a Roof.—This, in as far as the elevation of the rafters is to be considered, is found to vary in different climates. In Italy, and all the southern parts of Europe, it is made generally *less* than *one-fourth* of the span or breadth. In England, it was formerly *three-fourths*, but it is now made to approach much nearer to the Italian proportion. In northern climates, a steep roof is required, on account of the great falls of snow to which they are liable, and which greatly increase the lateral thrust of the rafters. For, the horizontal force exerted by a roof, if it be considered with reference to the walls which sustain it, is, in proportion to the length of a line perpendicular to the rafter descending from its extremity till it meets another similar line drawn from the opposite rafter, and this perpendicular is obviously increased when the roof is made very flat. But a flat pitched roof is stronger than a high one for resisting all transverse strains which tend to break the rafters.

Slaters class the Welsh Slates after the following Order and Designations, viz.

	Ft.	Inch.		Ft.	Inch.
Doubles, average size .	1	1	by	0	6
Ladies	1	3	by	0	8
Countesses	1	8	by	0	10
Duchesses	2	0	by	0	12
Welsh Rags	3	0	by	2	0
Queens	3	0	by	2	0
Imperials	2	6	by	2	0
Patent Slate	2	6	by	2	0

The slates, called *doubles*, are so called from the smallness of their size, and are made from the fragments of the larger qualities as they are sorted respectively.

The *ladies* are similarly obtained, being in pieces that will square up to the size of such a description of slate.

Countesses are still a gradation in dimension above ladies; and *duchesses* still larger. The slate is extracted from the quarries as other stony substances usually are, that is, by making perforations between its beds, into which gunpowder is placed and fused. This opens and divides the beds of the slate, which the quarrymen remove in blocks of very considerable size. These blocks are afterwards split by having wedges of iron driven between their layers, which separate the blocks into scantling, of from four to nine inches in thickness, and as long and wide as may be required. Some of the scantling, which is intended to be exported as such, is sawn to the sizes ordered, that is, the edges only of such pieces; for it is not necessary to use the saw to the horizontal stratum of the slate, as that can be divided nearly as correct by the above means, without having recourse to such a tedious process as the sawing of it would be.

For the purpose of sawing the slate, the works in Wales are provided with abundance of beautiful machinery, some of which is put in motion by steam, and others by water, which keep in action a vast number of saws, all sawing the scantlings of slate into pieces adapted to their several purposes.

The Imperial Slating for roofs is uncommonly neat; it is known by having its lower edge *sawn*, whereas all the other slates used for covering are chipped square on their edges only.

The Patent Slate is so called among the slaters from the mode adopted to lay it on roofs, as no patent was ever obtained for such a mode of slating. It was first brought into use by Mr. Wyatt, the architect. It allows of being laid on a rafter of much less elevation than any other kind of slate, and is considerably lighter by reason of the laps being so much more inconsiderable than is found to be necessary for the common sort of slating. This slating was originally made from that description of slates known as Welsh Rags. The slaters now frequently make it of Imperials, which gives to it still less weight, and renders it somewhat more neat in its appearance than by the former mode.

Of the Westmoreland Slate.—Some experiments have been instituted on this description of covering by the present Bishop of Landaff, and as there appears very little difference in the natural composition of this kind of slate from that which is obtained from Wales, the Bishop's comparison of their *absolute* weight as compared to that of other materials made use of as a covering to buildings may be of great utility, inasmuch as it may tend towards forming a data for adding to or diminishing from the quantity of timber employed in roofs of different spans and elevations.—"That sort of slate," says he, "other circumstances being the same, is esteemed the best which imbibes the *least* water, for the imbibed water not only increases the weight of the covering, but in frosty weather being converted into ice it swells and shivers the slate. This effect of the frost is very sensible in tiled houses, but it is scarcely felt in slated ones, for good slate imbibes but little water; and when tiles are well glazed they are rendered in some measure, with respect to this point, similar to slate." He adds, "I took a piece of Westmoreland slate and a piece of common tile, and weighed each of them carefully; the surface of each was about 30 square inches; both the pieces were immersed in water for ten minutes, and

and then taken out and weighed as soon as they had ceased to drip, and it was found that the tile had imbibed about one-seventh part of its weight of water, and the slate had not imbibed a 200th part of its weight. Indeed the wetting of the slate was merely superficial, while the tile in some measure became saturated with the water. I now placed both the wet pieces before the fire; in a quarter of an hour's time the slate was become quite dry and of the same weight it had before it was put into the water; but the tile had lost only about twelve grains of the water it had imbibed, which was as near as could be expected, the same quantity which had been spread on its surface, for it was this *quantity* only which had been imbibed by the *slate*, the surface of which was equal to that of the tile. The tile was left to dry in a room heated to 60° of Fahrenheit, and it did not lose all the water it had imbibed in less than six days. He adds further, "that the finest sort of Westmoreland slate is sold at Kendal at 3*s.* 6*d.* per load, which will amount to 1*l.* 15*s.* per ton, the load weighing two hundred-weight. The coarser sort may be had at 2*s.* 4*d.* a load, or 1*l.* 3*s.* 4*d.* per ton. Thirteen loads of the finest sort will cover forty-two square yards of roofing, and eighteen loads of the coarsest will cover the same quantity; so that there is half a ton less weight put upon forty-two square yards of roof, when the finest sort of slate is used, than if it was covered with the coarsest kind, and the difference of expense only three shillings and six-pence." It must be remarked, that it owes its lightness not so much to any diversity in the component parts of the stone from which it is split, as to the thinness to which the workmen reduce it, and it is not so well calculated to resist violent winds as that which is heavier.

On the comparison in weight of the sundry coverings employed on Roofs.—A common plain tile weighs thirty-seven ounces, and there are used, at a medium, seven hundred to cover a single square of roof of one hundred superficial feet. A pan-tile weighs seventy-six ounces, or four and three-quarter pounds, and one hundred and eighty are required to lay on a single square. Both the plain and pan-tiles are commonly bedded in mortar; indeed the former cannot be well laid on a roof without it. The mortar for the bedding of either will be equivalent to one-fourth of the weight of the tiles. When a roof is to be covered with copper or lead, it will depend upon what number of ounces of the metal it is determined to assign to each superficial foot of such covering. But for common lead or copper covering, supposing seven pounds of the former to the foot and sixteen ounces of the latter, the following comparisons will suffice; taking a square of one hundred feet superficial to be covered of each of the several materials, as all roofing is generally considered in such quantities, then it will be

	Cwt.	qrs.	lbs.
For Copper, per square,	0	3	16
Lead,	6	1	0
Fine slate,	6	0	21
For Coarser do.	8	1	8
Plain-tiles,	18	0	0
Pan-tiles,	9	2	0

Hence may be seen what each square of a roof sustains, and a careful builder may select such a covering as his building may be best calculated to support. It will be noticed too, how much the tiles exceed in their weight that of the other coverings. The pan-tile herein weighed, was at the time perfectly dry, and is of the common sort made in and about London. The plain tile is taken at the weight assigned it in the learned prelate's paper before referred to. The pan-tile is equally adapted to imbibe water with the plain tile, hence a somewhat greater weight than is here taken, may be supposed to be generally operating upon the roof, when loaded with such a covering.

Of the manner of laying Slates.—All the several kinds before named partake of a similar mode, in as far as refers to the *bonding or lap* of one portion of the slate over another. The lap of each joint is generally equal to *one-third* of the length of the slate, and the slater selects all the largest in size of the description about to be used, to be put on nearest the eaves of the roof. When the slates are brought from the quarry, they are not found in so square a shape as to be immediately fit to be put on a roof, but are prepared for that purpose by cutting and sorting. The slater, to effect this, picks and examines the slate, observing which is its strongest and squarest end. He then, by holding the slate a little slanting upon and projecting about an inch over the edge of a small block of wood, seating himself at the same time on something which is equal to it in height, begins and cuts away straight one of its edges. He then, with a slip of wood, gauges the other edge parallel to the same, and cuts off that also; after which he turns it round and squares the end. The slate is so far prepared, excepting it be the turning of his tool round and pecking through it, on its opposite end, two small holes, which are made for the nails to enter when he lays it on the roof. All the quarry slates require this preparation from the workman known as the slater. All slates are put on with nails or screws, and two are assigned to each slate at least. The copper and zinc nails are esteemed the best, by reason of their not being so susceptible of oxidation as the iron ones. The slaters, however, to prevent the destruction of their iron nails, have recourse to painting them; this they do by putting them in a tub containing white-lead, rendered very fluid by excess of saturation with oil, and stirring them up and about till they are completely covered over, after which they are removed and spread out upon boards and left to dry. Since the general developements of chemistry, some of the slaters have succeeded in plating over their iron nails with *tin*; but great address is necessary to succeed well at it; however, tinned nails are becoming more common, and will be found greatly cheaper than copper ones. The previous preparation necessary for laying slates on roofs,

consists in forming a base or floor for the slates to lay compactly and safely upon. For the *doubles* and *ladies*, boarding is essential, if it be expected to have a good water-proof covering to the roof. All that is required in the boarding for such slates is, that it be laid very even and the joints close, securing the boards by properly nailing them down on the rafters. When the boarding is ready, the slater examines it, and provides himself with several slips of wood, called *tilting fillets*. A tilting fillet is made about two inches and a half wide, three-quarters of an inch thick on one edge, and champered away to an arris on the other edge. These fillets he carefully lays and nails down all round the extreme edges of the roof to be slated, beginning with the hips, if there be any, and if not, with the sides, eaves, and ridge. When these are all done, he prepares for laying the slates, and begins the eaves first. For these he picks out all the largest slates, which he places regularly throughout, setting their lower edges to a line, and when so placed, he secures them by nailing them down to the boarding. He then selects such slates as will form the bond to the under sides of the eaves. This part of the work consists in placing another row of slates under those which he has previously laid, so as to cross and cover all their joints; such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for their support on the weight of those above them and their own weight on the boarding. The countesses and all the other description of slates, when intended to be laid in a good manner, are also laid on boards. When the slater has finished the eaves, he strains a line on the face of its upper slates parallel to its outer edge, and as far from it as he deems sufficient for the lap of those slates which he intends to go on to form the next course. This course of slates being laid and nailed even with the line, and crossing the joints of the upper slates of the eaves. This lining and laying of the slates is continued till the slater gets up close to the ridge of the roof, he observing throughout to cross the different joints by the slates he lays on one above another. This is the method uniformly followed in laying all the different kinds of slates, excepting it be those which are called *the patent* slates, which will henceforth be explained. All the larger kinds of slate are found to lay firmly on what are called battens, in consequence of which they are frequently made use of, from their promoting a saving in the expense, which will on an average amount to about twenty shillings per square. A batten consists of a narrow portion of deal-wood, about two and a half, or three inches wide; there are commonly three taken out flat-wise of a deal. When countesses are to be laid on, battens three-quarter inches in thickness will be an adequate substance for them; but for the larger and heavier kind of slates, inch battens will be necessary. When a roof is to be battened for slates, the slater himself is the best person to fix them, as they are not placed at an uniform distance from each other, but so as to suit the length of the slates, and as these vary as they approach the apex or ridge of the roof, it follows that the slater himself becomes the best judge where to fix the batten to best support the slates intended to lay on it. When they have been fixed by the carpenters he almost always finds it necessary to take them up and re-lay them. The nails used by slaters, as before observed are of iron, copper, and zinc. They are of the description called *clout-nails*. A clout-nail consists in being made round on its shank, or driving part, with a large round and flat head. Clout-nails are made of several qualities, but those used by the slater, are about an inch and a quarter long on the shank, and are termed eight-penny nails. The copper nails are considerably dearer than those of iron, or zinc, hence slating done by them is charged somewhat more per square.

The patent slating, as it is called, consists in selecting the largest slates, and those also of uniformity in their thickness.—The slates called *imperials*, are those now taken for it. A roof to be covered with this kind of slate, requires that its *common* rafters be left loose upon their purlins, as they must be placed so as to suit the widths of the slates, it being necessary to have a rafter under every one of their meeting joints.—Neither battening nor boarding is required for these *slates*, and the quantity of rafters will depend on the widths of the slates; hence if they are of a large size very few will be required, and of course a great saving in the timber will take place, besides giving a much less weight in the roof. The work of covering by this kind of *slate* is commenced as before at the eaves, but no crossing or bonding is wanted, the slates being uniformly laid, with the end of each reaching to the centres of each of the rafters, and are all butted up to one another throughout the length of the roof; the rafters being so placed as to come regularly under the ends of two of the slates. When the eave's course is laid, the slates composing it, are all screwed down by two or three strong one-and-a-half inch screws at each of their ends into the rafters under them. A line is *afterwards* strained about two inches from their upper edge, this being allowed as a lap for the course of slates which goes on above, the edges of which course being fixed straight with the line, and this lining laying with a lap and screwing down is continued till the roof is finally covered all over.—After which the filleting is to commence; this consists in covering all the meeting joints of the slates which come on the rafters with fillets of slate bedded in glaziers' putty, and screwing them down through the whole into the rafters under them.—The fillets to cover these kind of joints, are usually made about three inches wide, and as long as the slate they are intended to cover. They are solidly bedded in the putty, their joints lapped as is those of the slates; one screw is put in each lap, and one in the middle of the fillet; these fillets are after being so laid, bedded and screwed down, pointed neatly up all round their edges with more putty, and are painted over with a paint resembling the colour of the slate, and hence the work is deemed to be finished.—The hips and ridges of such slating

slating are frequently covered by fillets in a similar way, and have a very neat effect. But lead is the best covering for *all* hips and ridges of roofs, and it is not greatly dearer than covering them by this mode. Slating is done also in several other ways, but the principles before explained embrace the most of them; some workmen have shaped and laid their slates in a lozenge form. This kind of work consists in getting all the slates to a uniform size, and into the shape of a geometrical square; they are, when laying on the roof (which it is always necessary to have boarded for this work) bonded and lapped as the common slating is; observing only to exactly let the elbow or half of the square appear above each slate which is under it, and to be regular in the courses all over the roof. One nail or screw only can be used for such slating, hence it soon becomes dilapidated. It is commonly employed in places near to the eye, or where particular neatness is required.—*The patent slating* may be laid so as to be perfectly water-tight, with an elevation of the rafter considerably less than any other slate or tile covering; a rise of two inches in each foot to the length of the rafter is deemed an adequate rise for this covering, and this for a rafter of fifteen feet, would be only two feet six inches, a rise in the pitch of a roof which at any height from the ground would be hardly to be perceived.

Of the Slater's Tools.—They consist of a few only, and these are sometimes found by the master and sometimes by the men. The tool called the *saixe*, is composed of tempered iron, about sixteen inches in length, and two inches in width, somewhat bent at one end, and prepared for, and handled with beechen wood at the other.—This instrument is not unlike a large knife except its having on its back a piece of iron, projecting about three inches from out of it, and drawn sharp to a point. With this tool when ground sharp, the slater chips or cuts all his slates to the sizes he requires them for all the various purposes of his business.—He has also *a Ripper* as he calls it; this tool is formed of iron about the same length as the saixe, it is very thin in its blade part, which is one inch and three quarters wide, tapered somewhat towards its top, where it has a round head projecting over the blade on each side about half an inch, and having also two little round notches in the two internal angles at the intersection of the one with the other. There is a shoulder formed at the handle end of this tool, which raises it up above the blade, and which enables the workmen to hold it firmly in his hand when in use. The use of this tool is in repairs of old slating, as by forcing its blade up under the slates, the projecting head catches the nail of the slate, which enters into the little notch at its intersection, and which enables the workmen to pull it out, and which also at the same time loosens the slate, and allows him to take it away and insert another in its place, this is the principal use of the ripper, viz. the repairing of the old slating.

The hammer of the slater is somewhat different in shape from the common tool of that description; it is on the hammer, or driving part, about five inches in height, bent on the top a little back, and ground to a tolerably sharp point, its lower or flat end being about three quarters of an inch in diameter, and quite round. On the side of the driving part, is a small projection made with a notch in its centre, and which is used as a claw to draw or extract the nails, when nailing down the slates which do not drive satisfactorily. This kind of hammer is of great utility to the slater, and enables him to get through his new work with the greatest address.

The tool called the *shaving-tool*, is used for the purpose of getting the slates to a smooth face when so wanted, for skirtings, floors of balconies, or any other purpose to which slate may be required with a smooth face. It consists of a blade of iron, sharpened at one of its ends like a chisel, and is mortised through the centre of two round wooden handles, one of which is fixed at one end, and the other about the middle of the blade. The blade is about eleven inches long, and two inches wide. the handles to which are about ten inches long, so that they project four inches over on each side of the blade. The workman in using this tool, takes it in both his hands, placing one hand to each side of the handle which is in the middle of the blade, allowing the other to come up and press against the wrists of both his arms, and in this way he works away all the uneven parts from off the surface of the slate, and gets it to a smooth face. This tool is well calculated for what it has to do, but it is a very uneasy kind of instrument to the workman, its whole purchase in its operation upon the slate being against his wrists, and which is sometimes attended with so much pain that he is obliged to give over his work. To avoid this inconvenience, he often puts flannel and other things over the handle which lays against his wrists; still a day or two's work, with this tool, will lame an inexperienced workman.

The slater's other working tools consist of numerous chisels and gouges, together with files of all sizes, with which he finishes his slates for the better parts of his work into mouldings, and other forms, required for the different uses to which slate is applied.

The strength of slate is very great in comparison of any kind of freestone, as it is ascertained that a slate of one inch in thickness will support in an horizontal position as much in weight as five inches of Portland similarly suspended. Hence slates are now wrought and used for galleries and other purposes were strength and lightness combined are essential.

Slates are also fashioned into chimney-pieces, partaking of the different varieties of labour applied to marble; but it is incapable like it of receiving a polish, in consequence of which it will not get greatly into use for that purpose. It makes excellent skirtings of all descriptions, as well as casings to walls where dilapidations or great wear and tear is to be anticipated. It is capable of being fixed for these purposes with joints equally neat with wood, and may be painted over if required,

required, to appear like it. Staircases may be executed in slate, and will have an effect not unlike to black marble. The writer of this article has had a double gallery staircase leading to a *suite* of baths constructed of it, the effect of which was so good as by strangers to be generally taken and considered to be made of marble. Messrs. Warmsley and Milton, of Lambeth, are among the best slaters in London when slaters' work is required to be done on a large scale, or when any of the better departments of the working of slates are required, as they keep people competent to work it up into almost every shape, and with a neatness equalling works in marble.

Slaters' work is measured by the surveyors, as most artificers' work now usually is, and is afterwards reduced into squares, each square containing 100 feet superficial.

Slaters are allowed, in addition to the nett dimensions of their work (when taking the measure of roofs) six inches for all the eaves and four inches for the hips; this allowance is made in consequence of the slates being used double in the former case, and for the waste in cutting away the sides of the slates to fit into the latter. Some of these eaves, for instance, when rags or imperial slates are used, require an addition of nine inches to be allowed for the eaves, such kind of slates being so much larger than the size of most of the other kinds of slate now in use. All faced work in slate skirtings, staircases, galleries, &c. is charged by the foot superficial, admeasuring it without any kind of addition. The chimney pieces are made up and sold at per piece, as is done by the masons. Slating by the square to roofing varies as the size or quality of the *slate* made use of, beginning, for instance, with the *Doubles* at about two guineas, Countesses, &c. two guineas and a half, Welsh Rags and Imperials at three guineas and a half, and Westmoreland, the dearest of all, at four guineas and a half per square. The present prices of slaters' work done in a good and workmanlike manner, will be found to be equal to the above charges. Galleries and other slates worked up for such kind of purposes, and fixed complete, will vary as the mouldings about them do from 4*s.* 6*d.* to 5*s.* 6*d.* per foot superficial. Skirtings and linings of slate with one face only worked, but squared and fixed up, from 1*s.* 6*d.* to 2*s.* per foot superficial. From these data, a tolerably correct idea may be formed of the value of any kind of slating which may be wanting, and a comparison may be made of its value with the several other coverings, &c. employed in buildings.

SOAP-MAKING.

The combination of an oil with an alkali uniformly produces a compound, soluble in water, and in which the characteristic properties of oils and alkalies are destroyed or changed. These combinations are termed soaps; but as those of soda or pot-ash are only employed in the business, it is those alone that we shall at present particularly consider. It is probable, that ages must have elapsed before mankind arrived at a knowledge of the combination of oil and alkali, which we term soap. Saponaceous plants, argils, marls, and magnesia, appear all to have been employed in cleansing linen, long before the discovery of soap. We even see that some animal matters were employed with advantage for the same purpose. It is equally certain that the use of ash lyes preceded the discovery of soap. But the capability of combining oil with alkali so as to form a solid compound, soluble in water, and which can dissolve spots of grease, without changing the colour of the stuffs on which they are found, is a discovery of inestimable value in the arts. This discovery, successively improved, constitutes what is now termed the art of soap-making.

Of the Substances employed in the Manufacture of Soap.—Oils, tallow, and every kind of grease, are susceptible of combination with the alkalies, so as to form soaps; but they do not all furnish soap of an equally good quality. It is of importance then to ascertain the various matters that may be employed for this purpose, and shortly to point out the differences between them with the view of directing the choice of the manufacturer. Olive oil is generally employed in the preparation of soap. It combines perfectly with the soda; the soap thus produced is very white, uniform, of a proper consistence, and exhales an odour which is peculiar to this kind of soap. But every kind of olive-oil is not equally proper for saponification; three kinds are known in commerce—sweet, or virgin-oil; common, or dyer's-oil; and, expressed oil. The first is that which flows upon the pressure of the olive, the second requires a stronger degree of pressure, assisted by heat, and the third is produced by great pressure exerted on the refuse of the olives, in order to extract every remaining particle of oil, and which is always mingled with a considerable quantity of mucilage, and ligneous bodies.

bodies. The first is pure, and almost wholly free from any viscous principle. The second is mixed with a considerable portion of mucous matter, which forms, with the oil, a species of emulsion. The third contains little oil, and a great portion of the mucous and fibrous principle.

In order to ascertain whether the oil be of a good quality, we ought to have at hand an alkaline lixivium prepared without heat, and indicating from one to two degrees of concentration. Having introduced into a phial a few drops of the oil, the quality of which we wish to prove, we pour upon it some lixivium. Immediately upon the mixture becoming milky, we transfer it repeatedly from one phial into another, and allow it afterwards to remain at rest in the phial. If, after the lapse of a few hours, the combination remains uniformly white, and no particles of oil appear on its surface, we may rest satisfied that the oil is of a good quality; and, if the contrary, that it is bad. Pure oils require stronger lixivia than those of a coarser kind. Common oil is only employed in soap manufactures, not only because it bears a less price, but because it saponifies better. Fine oil is reserved for the use of our kitchens and tables. It is particularly from Italy, and chiefly from Genoa, that the French procure the best oil for their soap manufactures. Some oil is also imported from Barbary, which, conjointly with Genoa, supports the immense soap-works established at Marseilles. Next to olive-oil, that of sweet almonds yields the most consistent soap. But as this oil bears a high price, it is only employed in the composition of medicinal soap. Rape-oil forms a soap neither so consistent nor so white as the former. Hemp-seed oil produces a porous green-coloured soap, reducible to a paste by a small portion of water. Nut-oil forms a soap not proper for the hands; it is of a yellowish white colour, of a moderate degree of consistence, unctuous, gluey, and continues so on exposure to the air. The soap, of which linseed oil forms a constituent part, is, at first, white, but changes to yellow in a short time, on exposure to the air. It possesses a strong odour, is unctuous, clammy, glutinous, does not dry in the air, and softens with a very small quantity of water.

All the oils, of which we have spoken, are either oleaginous or fixed. The volatile oils are not, however, less susceptible of entering into combinations with the alkalies, but as these soaps are not employed in the arts, we shall not notice them in this article. Many animal substances are capable of combining with alkalies, and furnish us with valuable materials for the formation of soap. Suet forms, with soda, a white soap of an excellent quality; excepting only that it always retains a slight odour of grease, which it imparts to linen. Strong lixivia are necessary to the saponification of suet, or its conversion into soap. This soap requires much water to soften it, and destroy its consistency.

Butter may also be converted into soap by combining it with soda. The soap thus produced is white and solid.

Fish, and train-oils, produce soaps of a dirty grey colour, of a firm consistence, and retaining the smell peculiar to these oils. Oleaginous and fatty matters may be classed in the following order, as to their susceptibility of saponification. 1. Olive-oil, and that of sweet almonds. 2. Suet, butter, and the oil extracted from the fat of horses. 3. Oils drawn from rape-seed. 4. Oils procured from beech-mast, and clove July-flowers. 5. Fish-oil of different kinds. 6. Hemp-seed, nut, and lint-seed oils.

M. Chaptal long since proposed the employment of old wool, and the shreds and shearings of woollen cloth, for the formation of soap. Caustic alkaline lixivia readily dissolve these animal substances, and may be saturated with them, thus producing a saponaceous greenish paste, which might be successfully employed in the arts, for the fulling of cloth and other purposes.

In this country soap is usually made with tallow, or other fat; the process with oils being rather more difficult than that in which tallow is used. A good deal more of practical skill seems to be required in producing the proper union between oil and alkali, than between fat and alkali, and the process appears liable to sudden, and often unaccountable failures, from the refusal of the materials to unite with sufficient intimacy, or from their disunion after having been already combined.

Of Alkalies.—The three species of alkalies, soda, potash, and ammonia, may all be employed in the formation of soap. Soda and potash are the only alkalies employed in preparing the soaps of commerce. Ammonia is only used in forming some saponaceous composition for medicinal purposes. Soda forms firm and consistent soaps. Potash forms soft soaps, which attract humidity from the atmosphere. This difference proceeds from the nature of the alkalies, the former of which effloresces in the air, while the latter on exposure to it runs per deliquum. It rests not therefore with the artist to employ the soda or potash indiscriminately; his choice must be regulated by the kind of soap which he wishes to procure. All marine vegetables yield soda by incineration, but they do not furnish it in the same quantity or of the same quality. The alkali in the soda is always found mixed with marine salts and earthy matters; the best is that which contains the greatest portion of the alkaline principle. The only kinds of soda employed in the manufacture of soap, are the barilla, or soda of Alicant, the salicornia, or soda of Narbonne, Sicilian ashes, and natron. The sodas held in the highest estimation are those of Alicant, of which three kinds are to be found in the shops: 1. The mild soda, or mild barilla, which is of the best quality. 2. The soda properly so called, or the mixed barilla. This is hard, of a smooth fracture, of a greyish black colour, and with difficulty soluble in water. 3. Counterfeit soda, which is of the worst quality. The sodas of Carthagena possess nearly the same qualities as the mixed

barilla of Alicant. Sicilian ashes and those from the Levant, are inferior in quality to the sodas of Alicant, though when these last cannot be obtained, they are frequently made to supply their place. Natron is likewise very much employed; the low price at which it is sold during peace, operates to induce manufacturers to use it, though it contains very little pure alkali. Potash, properly so called, is rarely employed in this state for the formation of soap. Instead of it, the ley of ashes rendered caustic by lime is now very generally substituted.

Of solid Soaps, or Soaps of Soda.—The white and solid soap of commerce is composed of olive-oil and soda. The preparation of the leys, and the boiling of the soap constitute the principal operations in such manufactures.

Of the preparation of the Leys.—The alkalies, such as they are found in commerce, cannot be employed in the manufacture of soap. They must previously be deprived of the carbonic acid, the saline and earthy matters which they contain. This process is conducted in the following manner: Into a vessel about eight feet square and one foot deep is introduced quicklime, in the proportion of one-fifth to the weight of the oil intended to be converted into soap. Water is slightly sprinkled over this quicklime, which then grows hot, cracks, smokes, and falls down into powder, after which the soda, previously pounded, must be carefully mixed with it by means of a shovel. In order to favour the operation, a little water is occasionally added. As soon as the mixture is accomplished it is transferred into tubs. In small establishments their vessels are made of white wood, but in those which are on a larger scale they are composed of stone lined with bricks formed on the spot, and sunk into a mortar made with puzzolona or similar earths. Frequently these vessels are constructed of bricks laid flat, and cemented by a mortar of the same kind. These vessels are usually about five feet square by four and one-half feet in depth. They are perforated at the lower part of the side next the workhouse, with two holes or openings, which are closed by a stop-cock or pegs of wood. Under each of these vessels are placed two reservoirs constructed with the same care, and intended for the reception and preservation of the leys. At the bottom of these vessels are placed pieces of broken tiles to facilitate the efflux of the ley. When the mixture of the lime and soda has been transferred into the tub, there is poured on it a quantity of water sufficient to cover it to the height of a foot and a half. After leaving the water in this state for several hours, it is drawn off by means of a spigot into one of the reservoirs placed beneath. This ley marks from 15 to 20 degrees of concentration, and is called the first ley. After the ley has ceased to run and the spigot been shut, water is poured into the tub as before, and at the end of the four hours drawn off into the second reservoir. This is termed the second ley, and indicates between 10 and 12 degrees of concentration. A third ley is extracted with the same care; it only marks from 4 to 6 degrees. The soda is still further exhausted, by pouring on it a fourth water, and even a fifth if it appear necessary. The last leys are employed as common water, for the lixiviation of a fresh soda. When the soda is completely exhausted, the tubs are emptied, and the residuum thrown away as useless, or employed as manure on wet land.

Leys are powerfully influenced by the seasons; thus, in winter they are weaker, unless attention be given either to employ sodas of the best quality or in a greater quantity. The proportions of soda and lime employed are different, in different countries and in different establishments; in some they employ equal parts, while in others they use only one-sixth of quicklime. This difference appears to depend on the lime, and more frequently on the nature of the soda. In general old sodas and natrons require the most lime. Lime in a state of efflorescence, possesses not the same power as that which is newly made; and as this is not always at hand, we preserve it in proper repositories sheltered from the contact of air and moisture, in order to obviate all change. It is seldom that the manufacturers of soap confine themselves to one kind of soda in the formation of the lixivium; they for the most part employ a mixture in different proportions of natron, Alicant soda, Sicilian ashes, the Salicornia of Narbonne, &c.

Of the boiling of Hard Soap.—The art of combining oil with caustic soda, and of reducing this combination to a suitable degree of consistence is the most difficult and the most important operation of soap-making. This combination is performed in a caldron, and by the aid of heat. The caldron used in soap-manufactures is of a peculiar construction; the lower part of it is of copper, while its sides are constructed of mason or brick-work. Much skill and dexterity are requisite in erecting such furnaces, for it must be obvious that if the junctures be not well closed the matter would escape. On the other hand, the expense attendant on their erection is so great, and the suspension of the labour so inconvenient, that nothing should be neglected to give to them the greatest possible degree of solidity. If the operations be performed in caldrons entirely metallic instead of those above-mentioned, not only will the soap be less white, but the management of the process will be rendered extremely difficult, inasmuch as the metal being a more ready conductor of heat than stone, occasions the saponaceous matter to boil over and burn.

The manner of boiling the soap likewise varies in different establishments; in some they employ weak lixivia, and in others that which is very strong. We shall here, as succinctly as possible, describe these two methods. The lixivia being prepared, the next step is to put into the caldron all the oil intended to be employed. It is not, however, possible previously to ascertain the exact quantities of oil and soda, as these proportions vary according to the nature of the soda and oil,

oil, and can therefore only be known from experience. In general, six parts of olive-oil are used with five of soda. In some soap-houses the oil is boiled previously to the addition of the ley; but when the oil is extremely thick and contains many impurities, it is mixed with a strong lixivium and then boiled: the clear and transparent oil quickly rises and ascends to the surface, while the impurities are precipitated. The fire is then stopped, and the workman removes the supernatant oil from the gross matters which have subsided.

After cleaning the caldron, and returning into it the oil which had been taken off, he rekindles the fire and proceeds to the boiling. He pours some buckets of the weakest ley on the oil, and digests the whole with a gentle heat, which is carefully kept up, till the soap be completely made. The combination is facilitated by incessantly agitating the mixture with a long wooden spatula. There is added, gradually, more of the same lixivium; and, when it is exhausted, the second is employed. The oil gradually combines, the matter thickens, and becomes white; more of the first ley must then be added, after which the paste soon becomes more consistent, and separates imperceptibly from the aqueous liquor. Some chemists advise us, at this moment, to throw into the caldron a few pounds of sea-salt, in order to produce a more complete separation; the paste then assumes a grained form, having some resemblance to spoiled cream; the ebullition is maintained, during two hours, after which the fire is withdrawn, and the agitation discontinued. When a few hours have elapsed, the liquor, which remains at the bottom of the caldron, is drawn off by means of a pipe, communicating with its inferior part; the fire is rekindled; the soap is dissolved by the aid of a little water poured into the caldron; the mixture is agitated, and when it is completely liquified, and in a boiling state, the remainder of the first ley is gradually added to it.

We ascertain that the soap has attained a due degree of consistence: 1, by allowing a small portion of it to fall and coagulate on a slate; 2, if, on shaking a spatula, dipped into the paste, briskly in the air, the soap is detached in the form of ribbons, without adhering to the wood; 3, by the peculiar odour of soap, by handling it between the fingers. Although the method of graining the soap, and separating the aqueous part be far from common, yet it has been successfully employed in many establishments since it was made known. The process may unquestionably be conducted without the aid of salt; but as it frequently happens that the process fails toward the conclusion, and thereby embarrasses even a skilful manufacturer, it may not be improper to point out the means of remedying it. In some manufactures the strongest lixivium is employed at the commencement of the ebullition; by which method the paste becomes quickly thickened to a considerable degree, and requires to be managed by persons skilled in such operations. It is judged necessary to pour in fresh ley, when the paste sinks down, and remains at rest. They continue to employ the strong ley till it be nearly exhausted. Then the boiling subsides, that is, it sinks down, and appears as if stationary; it boils in this manner during three or four hours; after which it is moistened by pouring into it the second lixivium, while care is at the same time taken progressively to augment the heat. It very rarely happens, when the strongest lixivium has been used at the beginning, that the third ley is necessary. This is only employed when the paste does not boil, because then the object is to dilute it. As soon as the boiling is finished, the fire is withdrawn; the lixivium is then drawn off, after which the paste is left to cool, and taken up before it be fully coagulated, by means of copper or wooden buckets, to be transferred into moulds, into the bottoms of which, a portion of pulverized lime has been previously introduced, to prevent the soap adhering to them. At the end of two or three days, when the soap becomes sufficiently hard, they remove it from the moulds, and divide it into wedges of different sizes, by means of a brass wire. They place these wedges on a floor edge-wise, where they are allowed to remain till they become perfectly firm and dry. The fair trader lays his account in procuring five pounds of soap from three pounds of oil. The soap is not marketable, till it ceases to receive any impression from the fingers. It must not be supposed that the lixivium employed at the commencement of the process should be constantly continued. The great art of soap-making consists in knowing how to determine, from the appearance of the paste, and other circumstances, what kind of lixivium should be employed during each step of the operation. The overseers regulate their conduct in this respect by observation and experience. The form and size of the bubbles, the colour of the paste, the volume of that which is thrown out on the edges of the vessel, the consistence of the matter, and its disposition to swell, as well as the appearance of the steam, all furnish them with marks by which they regulate their conduct.

With respect to the proportion of ingredients, it is reckoned that sixteen bushels of good wood-ashes, are equal to one hundred-weight of the best pearl-ash, and that this latter quantity will saturate two hundred-weight of tallow, and produce three hundred and a quarter weight of soap, so that twelve parts of tallow will make twenty pounds of soap. Again, twelve bushels of wood ashes are reckoned equal to one hundred-weight of barilla, and this will saturate one hundred and a half-weight of tallow. A boil of twenty-nine hundred-weight of tallow with ten hundred-weight of barilla, and five hundred-weight of pearl-ash requires eight hundred-weight of common salt. The common yellow soaps are made in this country with tallow and barilla, to which after saponification, is added a quantity of rosin, and sometimes a little palm-oil and the materials thoroughly incorporated. The following materials and proportions are said to make a good yellow soap: twenty-five hundred-weight of tallow, four hundred-weight and a half of oil, seven hundred-weight of rosin, eighteen hundred-weight of barilla, ten hundred-weight of black ashes, or waste ley evaporated

porated and calcined, and half an hundred-weight of palm oil. They produce sixty-four hundred-weight of soap.

In manufactures of white soap, it is usual to vein some portions of it, of a blue colour, in order to form what is termed marbled or mottled soap. The oxydes of iron are employed for this purpose; but it is not till after two days' boiling that they begin the process of variegation. With this view, a one hundred and fortieth part of the sulphate of iron, relatively to the oil intended to be formed into soap, is diluted, and decomposed with a weak lixivium.

Marbled soap is harder than that which is white, and is preferred to it for washing. This hardness, probably, does not merely proceed from the parts of the paste being brought into closer contact, but from a portion of oxygen abandoning the oxyde to combine with the iron. What tends to strengthen this hypothesis is, 1st, That the marbled soap never acquires its genuine quality, until by ebullition, the colour of the oxyde has been reduced to a blackish tint. 2d, Because white soap, though very hard, never assumes the same character as the marbled. At all times has the soap manufactured at Marseilles, stood deservedly high in the public estimation; cupidity has, it is true, sometimes operated on certain individuals to impose this article on customers, in an adulterated state; but the manufacturers, who are necessarily interested in supporting its character, have never failed on such occasions to stigmatize them as they deserve.

Apothecaries and druggists prepare a medicinal soap by combining two parts of oil of almonds and one part of soap leys, so concentrated, that a phial which is capable of holding eight ounces of water, may contain eleven of ley. The soap thus prepared acquires consistency within a few days. It retains sometimes a caustic taste for a short period, but this may be obviated by combining with it a fresh portion of oil, or by preparing it with greater care at first. The grease collected in kitchens, may be employed in the composition of soaps, prepared without the aid of heat. With this view, to six pints of lixivium, must be gradually added, constantly shaking the mixture, three pounds of grease, melted in a copper basin. The basin is kept on warm ashes for one hour, while at the same time the agitation is continued. It is then taken from the ashes, and agitated again for half an hour, till the mixture thickens. The saponaceous paste thus prepared, is run into an earthen pan, in which it is left to the following day, when being stirred, it is poured into moulds. Within three or four days it is taken out of the moulds, and set to dry, till it acquires a suitable degree of hardness.

Of soft Soaps.—Soft soap is composed of potash and oil. This soap is very useful in scouring and cleansing stuffs from greasy matters with which they happen to be soiled. The greatest manufactures of soft soap are established in Flanders, Picardy, and Holland. The fish oil used by the Dutch, which imparts a disagreeable odour to the soap, has not a little contributed to bring their manufacture of this kind of soap into discredit. The use of this oil is prohibited by law in Flanders and in Picardy. The oils employed in these countries, for similar purposes, are generally those drawn from flax, hemp, and rape seed. These are distinguished by the appellation of warm and cold oils. Those which the Flemings denominate warm oils, the inhabitants of Picardy call yellow oils, and restrict the term green oil to cold oil. The warm oils bear a higher price than those called cold; and on this account they are frequently mixed. The kinds of potash employed for the formation of soap, are procured from the North, or from Alsace. The caldrons are composed of plates of hammered iron, fastened together with rivets. After introducing into the caldron the half of the oil intended for one coction, the fire is kindled, and when the oil begins to grow hot, we add to it a portion of the lixivium; what remains of the oil and the lixivium must afterwards be gradually poured in during the ebullition. If too much of the lixivium be employed at the commencement, no combination takes place; if the lixivium be too strong, the mixture separates into clots, and if it be too weak, the union is incomplete. The quantity of the lye employed in one coction, ought to be in the proportion of four parts to three of the oil. Two hundred parts of oil, and one hundred and twenty-five of potash, yield three hundred and twenty-five of soap. When the union is fully accomplished, and the liquor is rendered transparent, nothing remains but to employ the necessary degree of coction. The soap-boilers judge of the degree of coction by the consistence, by the colour, and from the time which the soap takes to coagulate. In order to make the froth subside, and render the mass fit for barrelling, one ton of soap is emptied into the caldron. The soap held in the greatest request is of a brown colour inclining to black.

Of Domestic Soap.—The only advantage in rendering soap of a hard and solid form is to facilitate its carriage, and to adapt it to certain manipulations; but for a great variety of purposes, it is reduced into a liquid state, to render its employment more convenient. For domestic purposes, the operation of coction in the preparation of soap, might, perhaps, be superseded, by the formation of saponaceous liquor, well adapted for the purpose of cleansing and whitening of stuff and linen.

"The preparation and employment of these saponaceous liquids have," says M. Chaptal, "long engaged my attention, and as my experiments on this have been attended with the happiest success, I shall here enter into some details respecting them. 1. We employ either the potash sold in the shops, or a strong ley of common ashes. In the first case we pour water on the potash, and allow it to dissolve, till the solution marks two degrees of concentration. We then decant this solution, and pour it on a portion of oil contained in a vessel. The mixture instantly becomes of a white colour, and forms a milky liquor. In general, we ought to employ a small quantity of oil, and at most, not more

more than the proportion of one-fortieth part to the bulk of the ley. In the second case, we mix a portion of quick-lime with the ashes we mean to employ, and then lixiviate them, in the usual manner. This lixivium is used, like the solution of potash, after having been brought to the proper degree of concentration. This lixivium should always be prepared immediately before being used; and for this purpose recent ashes answer better than those that have been long kept. The coarser oils, termed dyer's oils, are also preferable to the purer kinds in the composition of this mixture. When they exhale a disagreeable odour it is communicated to the linen; but this fault may easily be corrected, by rincing it through a pure lixivium. When the liquor is too thick, it ought to be diluted with a weak lixivium; it should likewise be agitated, and beaten up to a froth, before being employed. When soda is used instead of potash, it must first be grossly pounded, and then put into a vessel, and covered with water, by which means we obtain a solution marking two degrees of concentration. The oil being put into a proper vessel, from forty to forty-five parts of the solution of soda is poured on it, when the mixture immediately assumes a milky appearance, which it ever afterwards retains, if the oil and soda be of a good quality. The Alicant soda is the best with which we are acquainted, and the addition of lime will be found unnecessary, except the soda be old, or in a state of efflorescence. *Several lixivia* may be thus formed, by pouring fresh water on the undissolved soda. Independently of these very simple processes, soaps may be formed with rancid butter, and other oily and greasy substances, rejected in the kitchen. I have also succeeded in procuring a soap from wool; which, at the same time that it is extremely economic, possesses very excellent qualities. To prepare this soap, it is sufficient to saturate a boiling lixivium with the wool rejected in our manufactures. This soap answers extremely well for scowering or cleansing stuffs. The British prepare a very economic soap from the remains of the fish which are employed in the formation of glue, and of those that are salted for the market. Cases may occur, in which, though possessing potash, marine salt, and oil, it is impossible to find a supply of soda proper for saponification; yet, even under such circumstances, hard or solid soap may be prepared by decomposing the soap of potash by the marine salt. Thus, for example, if we combine three pounds of oil with a sufficient quantity of potash to form a soft soap, nothing more is requisite, but gradually to add, towards the end of the process, six pounds of marine salt. The saponification is begun with the potash, and completed by the salt."

Of the Uses of Soap.—The first and most important use of soap is, that of scowering or cleansing stuffs, because it possesses the property of uniting with the oil or grease by which they are soiled, and rendering them soluble in water without dissolving or changing the texture of woollen, silk, or cotton fabricks of any kind whatever. The manner of scowering or washing varies according to the nature of the cloth and the consistence of the soap; when the soap is hard, hand-washing is usually employed, or, in other words, the soap is rubbed upon the cloth itself, with the view of forming a direct combination between the oil or grease contained in it and the soap; the matters thus combined are then washed out by the aid of water. The soap is frequently dissolved in water; and this saponaceous liquor is used to impregnate the cloth, and extract from it by repeated friction and the employment of water all the greasy matters with which it is imbued. Woollen cloth, blankets, flannels, and indeed all animal substances, are most effectually cleansed by soft soaps, or soaps of potash. Some waters are not favourable to the solution of soap; those impregnated with earthy salts decompose it. Soda-soap forms the basis of wash-balls. With this view it is melted and then mixed with fine starch, which is the only article besides the soap used in the preparation of the common kinds. The usual proportions are three parts of starch to five of soap; the soap being cut into finger lengths is melted in a caldron, and two-thirds of starch thrown in, care being taken to stir it frequently; it is next poured on a board or smooth table, and the remaining third of the starch kneaded into it with the hand until they be sufficiently incorporated; after which the paste is made up into the shape that may be desired. Another kind of wash-balls is prepared by dissolving white soap in alcohol. For this purpose alcohol is digested upon soap previously cut into finger-lengths, and at the end of twenty-four hours this mixture or paste is triturated in a mortar, with aromatics reduced to powder, or with a small quantity of some aromatic oil, such as that of jasmine, tuberose, lemon, citron, and orange. When the paste is become sufficiently consistent, it is formed into balls which exhale an agreeable perfume. Sometimes the aromatics are incorporated with mucilage of gum tragacanth, and whites of eggs. It is customary, in some manufactures to prepare an aromatic dye, by infusing different aromatic substances in alcohol, and afterwards kneading a portion of it with the soap, to which it imparts a strong perfume. Different saponaceous essences are prepared by dissolving aromatic soaps in double their weight of ardent spirits.

STAINING OF PAPER.

The colours proper for staining of paper are the same as those used for other substances, and they are applied with soft brushes, after being well tempered to a due degree of subsistence with size, gum-water, &c. If the paper on which they are laid is soft, so that the colours are apt to go through, it must be fixed before they are laid on, or a proportionally larger quantity must be used with the colours themselves. If a considerable extent of the paper is to be done over with one colour, it must receive several coatings, as thin as possible, letting each coat dry before another is put on, otherwise the colour will be unequal.

Take yellow ochre, grind it with rain-water, and lay a ground with it upon the paper all over; when dry take the white of eggs, beat it clear with white sugar-candy, and strike it all over: then lay on the leaf gold, and when dry polish it with a tooth. Some take saffron, boil it in water and dissolve a little gum with it, then they strike it over the paper, lay on the gold, and when dry they polish it.

Take two scruples of clear glue made of neats' leather, one scruple of white alum, and half a pint of clear water, simmer the whole over a slow fire till the water is consumed or the steam ceases. Then, your sheets of paper being laid on a smooth table, you dip a pretty large pencil into that glue, and daub it over as even as you can, repeating this two or three times: then sift the powder of talc through a fine sieve made of horse-hair or gauze over it, and then hang it up to dry, and when dry rub off the superfluous talc, which serves again for the same purpose. The talc you prepare in the following manner: take fine white transparent Muscovy talc, boil it in clear water for four hours; then take it off the fire, and let it stand so for two days; then take it out, wash it well, and put it into a linen rag, and beat it to pieces with a mallet; to ten pounds of talc add three pounds of white alum, and grind them together in a little hand-mill, sift it through a gauze-sieve, and being thus reduced to a powder put it into water and just boil it up; then let it sink to the bottom, pour off the water from it, place the powder in the sun to dry, and it will become of a hard consistence; beat this in a mortar to an impalpable powder, and keep it for the use above-mentioned, free from dust.

The common grounds laid in water are made by mixing whitening with the common glovers' size, and laying it on the paper with a proper brush in the most even manner. This is all that is required where the ground is to be left white; and the paper being then hung on a proper frame till it be dry, is fit to be painted. When coloured grounds are required, the same method must be pursued, and the ground of whiting first laid, except in pale colours, such as straw colours or pink, where a second coating may sometimes be spared, by mixing some strong colour with the whitening.

There are three methods by which paper-hangings are painted; the first, by printing on the colours; the second, by using the stencil: and the third, by laying them on with a pencil, as in other kinds of painting.

When the colours are laid on by printing, the impression is made by wooden prints; which are cut in such a manner that the figure to be expressed is made to project from the surface by cutting away all the other part; and this, being charged with the colours tempered with their proper vehicle, by letting it gently down on a block on which the colour is previously spread conveys it from thence to the ground of the paper, on which it is made to fall more forcibly by means of its weight, and the effort of the arm of the person who uses the print. It is easy to conclude, that there must be as many separate prints as there are colours to be printed. But where there are more than one, great care must be taken after the first to let the print fall exactly in the same part of the paper as that which went before, otherwise the figure of the design would be brought into irregularity and confusion. In common paper of low price, it is usual, therefore, to print only the outlines, and lay on the rest of the colours by stencilling, which both saves the expense of cutting more prints, and can be practised by common workmen, not requiring the great care and dexterity necessary to the using several prints.

The manner of stencilling the colours is this. The figure, which all the parts of any particular colour make in the design to be painted, is to be cut out in a piece of thin leather or oil-cloth, which pieces of leather or oil-cloth are called stencils; and being laid flat on the sheets of paper to be printed, spread on a table or floor, are to be rubbed over with the colour properly tempered by means of a large brush. The colour passing over the whole is consequently spread on those parts of the paper where the cloth or leather is cut away, and gives the same effect as if laid on by a print. This nevertheless is only practicable in parts where there are only detached masses or spots of colours; for where

where there are small continued lines, or parts that run one into another, it is difficult to preserve the connexion or continuity of the parts of the cloth, or to keep the smaller corners close down to the paper: and, therefore, in such cases, prints are preferable. Stencelling is indeed a cheaper method of ridding the work than printing; but without such extraordinary attention and trouble as render it equally difficult with printing, it is far less beautiful and exact in the effect. For the outlines of the spots of colour want that sharpness and regularity that are given by prints, besides the frequent extralineations or deviations from the just figure, which happen by the original misplacing of the stencils, or the shifting the place of them during the operation.

Pencilling is only used in the case of nicer work, such as the better imitations of the India paper. It is performed in the same manner as other painting in water or varnish. It is sometimes used only to fill the outlines already formed by printing, where the price of the colour or the exactness of the manner in which it is required to be laid on, render the stencilling or printing it less proper; at other times it is used for forming or delineating some parts of the design, where a spirit of freedom and variety, not to be had in printed outlines, are desired to be had in the work.

The paper designed for receiving flock is first prepared with a varnish-ground with some proper colour, or by that of the paper itself. It is frequently practised to print some mosaic or other small running figure in colours on the ground before the flock be laid on; and it may be done with any pigment of the colour desired, tempered with varnish, and laid on by a print cut correspondently to that end.

The method of laying on the flock is this. A wooden print being cut, as is above described, for laying on the colour in such manner that the part of the design which is intended for the flock may project beyond the rest of the surface, the varnish is put on a block covered with the leather or oil-cloth, and the print is to be used also in the same manner, to lay the varnish on all the parts where the flock is to be fixed. The sheet thus prepared by the varnished impression is then to be removed to another block or table, and to be strewed over with flock, which is afterwards to be gently compressed by a board or some other flat body, to make the varnish take the better hold of it, and then the sheet is to be hung on a frame till the varnish be perfectly dry; at which time the superfluous part of flock is to be brushed off by a soft camel's-hair brush; and the proper flock will be found to adhere in a very strong manner.

The method of preparing the flock is by cutting woollen rags or pieces of cloth with the hand, by means of a large bill or chopping-knife, or by means of a machine worked by a horse-mill.

There is a kind of counterfeit flock-paper, which when well managed has very much the same effect to the eye as the real, though done with less expense. The manner of making this sort is, by laying a ground of varnish on the paper; and having afterwards printed the design of the flock in varnish in the same manner as for the true, instead of the flock some pigment or dry colour of the same hue with the flock required by the design, but somewhat of a darker shade, being well powdered is strewed on the printed varnish, and produces nearly the same appearance.

STARCH-MAKING.

If a quantity of wheat-flour be formed into a paste, and then held under a very small stream of water, kneading continually till the water runs off from it colourless; the flour, by this process, is divided into two constituents, viz. a tough substance, called gluten, which remains in the hand, and the water, which, running off white, deposits a white powder, known by the name of *starch*. The starch obtained in this manner is not altogether free from gluten, and, accordingly, its colour is not very white, and it has not that fine crystallized appearance which distinguishes the starch of commerce. Manufacturers employ a more economical and more efficacious process, which it will be our business now shortly to describe.

The mode of manufacturing the common starch, which is made for sale, is almost exclusively from wheat, though potatoes are sometimes used. This grain consists of gluten, fecula, a colouring extractive matter, and phosphate of lime; and it is the object of the starch-maker to separate the fecula alone from all the other ingredients.

Wheat-starch is made in the following manner:—The grain, after being coarsely ground, is suffered to ferment with water for many days, by which its texture is entirely

entirely broken down, and the starch, which is scarcely alterable in the process, is probably more effectually separated from all the other ingredients, and obtained finer and whiter. The actual method is this:—The wheat is first coarsely bruised, and placed in large wooden vats water-tight, and intimately mixed with water. Here a fermentation begins after a time, which is a mixture of the vinous and acetous, and is attended with a strong, sour, mouldy smell. The wheat remains in the vat for about a fortnight, till the fermentation ceases, which is known by its settling at the bottom of the vat. The contents are then emptied into a small tub, and mixed with fresh water, till all the pulpy part is thin enough to pass through a hair sieve, which separates the bran. What has gone through contains the starch, suspended in a very sour water, and considerably foul. This is put into tubs, and allowed to remain for two days undisturbed, during which the impure starch settles to the bottom. The water is then drawn off, the tubs or frames turned on their sides, and the dirty discoloured part of the starch, which is the last that subsides, and therefore is at the top, is scraped off, and the remaining starch is well washed and brushed, till it is nearly free from the muddy sediment, which is called *slimes*, and is treated separately to obtain its starch. The starch is stirred with fresh water, suffered to settle, and again cleansed, till its impurities are removed; it is then mixed with water enough to make it liquid, and passed through a fine lawn sieve. It is then fit to receive its bluish colour, which consists of smalt mixed with water and a small quantity of alum, to be thoroughly incorporated with the starch. After settling once more, the starch is taken out and put into oblong boxes, about six feet long and one broad, with holes at the bottom, and lined with linen cloth, where the moisture of the starch drains off till it becomes solid enough to be cut into square lumps. These are laid on bricks which absorb much of the moisture, and make them sufficiently hard to be stoved. Here the starch remains in a moderate heat, till a slimy crust rises to the surface, which is carefully scraped off, and the rest, which is now pure starch, is prepared and placed again in the stove with a good hot fire, till it is quite dry. This last stoving causes the lumps to crack pretty uniformly into the small pieces in which they appear when sold. The slimes are treated in the same way till all the starch is separated. All the refuse matter from starch-making affords very valuable food for fattening hogs. The whole time of making starch, from the first steeping of the wheat to the last stoving, is about five or six weeks; five hundred and fifty-one Winchester bushels of wheat will make about six ton of starch. This will be about $\frac{1}{7}$ of the weight of the wheat.

In the process of starch-making a great quantity of a sour nauseous milky water is obtained, from which the starch subsides after it is removed from the fermenting vat. This has been analyzed with great care by Vauquelin, and is found to contain the following substances, viz. acetous acid, ammonia, alcohol, gluten, and phosphate of lime; but, of these, only the two last are natural to the wheat, the others are, undoubtedly, the products of the fermentation, the ammonia being generated by the decomposition of part of the gluten, the alcohol by the saccharine mucilage which every species of grain contains, and the acetous acid, perhaps, from all the other principles. The peculiar office which this acid performs in starch-making is to dissolve the gluten, and phosphate of lime, and thus to separate them from the pure starch. Hence, when wheat is employed, arises the necessity of continuing the fermentation long enough to generate a sufficient quantity of acetous acid; for the other grains and roots, which afford starch, contain little or no gluten. A considerable quantity, however, of the starch must be destroyed in the process, for wheat contains much more of it than is obtained in the manufacture, as may be found by washing flour-paste with water, in the way mentioned in the beginning of this article.

Starch has a fine white colour, and is usually concreted into longish masses; it has scarcely any smell, and very little taste. It does not dissolve in cold water, but falls to powder. It combines with boiling water, and forms with it a kind of jelly, which may be diffused through boiling water, but when the mixture is allowed to stand a sufficient time, the starch slowly precipitates to the bottom.

TALLOW AND WAX-CHANDLERY.

These trades, when united, consist principally in the manufacture of candles. A candle has been defined a cotton wick, loosely twisted, and covered with tallow, wax, or spermaceti, in a cylindrical figure, which, being lighted at the end, serves to illuminate the place in the absence of the sun. In general, the trades are distinct, the tallow-chandler manufacturing tallow-candles only; the wax and spermaceti being made by the wax-chandler.

The cotton used for dipped, or common candles, is

is brought from Smyrna, in the wool, which grows on trees in the shape of nuts; the shells enclosing the cotton. The cotton for moulded candles comes from Turkey, and the adjacent countries, packed in bales, which, when brought to England, is made to perform quarantine, lest in the unpacking on shore, it should be infected with some pestilential disorder.

The tallow-chandler employs women to wind the cotton into large balls; he then takes five, six, or eight of these balls, and drawing out the threads from each, cuts them into proper lengths, according to the size of the candles wanted. The machine for cutting the cotton is a smooth board, made to be fixed on the knees; on the upper surface are the blade of a razor, and a round piece of cane, placed at a certain distance from one another, according to the length of the cotton wanted: the cotton is carried round the cane, and being brought to the razor, is instantly separated from the several balls.

The next operation is denominated "pulling the cotton," by which the threads are laid smooth, all knots and unevennesses removed, and, in short, the cotton is rendered fit for use. It is now spread, that is, placed at equal distances, on rods about half an inch in diameter and three feet long; these are called "broaches."

A tallow-candle, to be good, must be of sheeps' and bullocks' tallow. The wick ought to be pure, sufficiently dry, and properly twisted, otherwise the candle will emit an inconstant vibratory flame, which is both prejudicial to the eyes and insufficient for the distinct illumination of objects.

There are two sorts of tallow-candles; the one dipped, the other moulded: the former are common candles. The tallow is prepared by chopping the fat, and then boiling it for some time in a large copper; and when the tallow is extracted by the process of fire, the remainder is subjected to the operation of a strong iron press, and the cake that is left after the tallow is expressed from it is called greaves: with this dogs are fed, and the greater part of the ducks that supply the London markets.

When the tallow is in proper order, the workman holds three of the broaches with the cottons properly spread between his fingers, and immerses the cotton into the vat containing the tallow: they are then hung on a frame and suffered to cool; and when cold they are dipped again, and so the process is continued till the candles are of a proper size. During the operation, the vat is supplied from time to time with fresh tallow, which is kept to the proper heat by means of a gentle fire under it.

An invention of modern date has taken off much of the labour of the tallow-chandler, in dipping candles: this consists in the mode of dipping. The wicks are prepared as has been described, and spread on the broaches, and when five or six of these broaches are filled with cotton, they are, at both ends, fixed into two small pieces of box wood, so as to unite, as it were, the several broaches into one moveable frame, full of wicks. This frame is suspended on one end of a lever, over the vat, while the other is balanced with weights in a scale, which may be increased as the candles become larger and heavier. The workman, by this simple and excellent contrivance, has only to guide the candles, and not to support the weight of them between his fingers.

The mould, in which the moulded candles are cast, consists of a frame of wood, and several hollow metal cylinders, generally made of pewter, of the diameter and length of the candle wanted: at the extremity of these is the neck, which is a little cavity in form of a dome, having a moulding withinside, and pierced in the middle, with a hole big enough for the cotton to pass through. The cotton is introduced into the shaft of the mould by a piece of wire being thrust through the aperture of the hook till it comes out of the neck: the other end of the cotton is so fastened as to keep it in a perpendicular situation, and in the middle of the candle; the moulds are then filled with warm tallow, and left to be very cold before they can be drawn out of the pipes.

Besides these, there are other candles made by tallow-chandlers, intended to burn during the night without the necessity of snuffing: the wick has been usually made of split rushes; but lately very small cotton wicks have been substituted for the rush: these are lighted much easier, are less liable to go out, and, owing to the smallness of the cotton, they do not require the aid of snuffers.

To make Wax-candles with the Ladle.—The wicks being prepared, a dozen of them are tied by the neck, at equal distances, round an iron circle, suspended directly over a large bason of copper, tinned and full of melted wax: a large ladleful of this wax is gently poured on the tops of the wicks one after another, and the operation continued till the candle arrives at its destined bigness, with this precaution, that the first three ladles be poured on at the top of the wick; the fourth at the height of three-fourths, the fifth at one-half, and the sixth at one-fourth, in order to give the candle its pyramidal form. Then the candles are taken down, kept warm, and rolled and smoothed upon a walnut-tree table, with a long square instrument of box, smooth at the bottom.

As to the manner of making wax-candles *by the hand* the workmen begin to soften the wax by working it several times in hot water, contained in a narrow but deep caldron. A piece of the wax is then taken out, and disposed by little and little around the wick, which is hung on a hook in the wall, by the extremity opposite to the neck; so that they begin with the large end, diminishing still as they descend towards the neck. In other respects the method is nearly the same as in the former case. However, it must be observed, that in the former case water is always used to moisten the several instruments, to prevent the wax from sticking; and, in the latter, oil of olives, or lard, for the hands, &c. The cylindrical wax-candles are either made as the former, with a ladle, or drawn. Wax-candles, or tapers drawn, are so called because they are actually drawn in the manner of wire

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by means of two large rollers of wood turned by a handle, which turning backwards and forwards several times, pass the wick through melted wax contained in a brass bason, and at the same time through the holes of an instrument like that used for drawing wire, fastened on one side of the bason.

The wax-chandler makes and sells sealing-wax, and wafers. It is from the combination of lac with Venice turpentine, sealing-wax is formed. Four parts of lac are said to be melted with two of turpentine, and two of resin: the composition is coloured *red* by the addition of one part of cinnabar and one of red-lead; or *black*, by the addition of lamp-black.—See Murray's Chemistry, vol. iv.

Wafers are said to be made in the following manner: —Take very fine flour, mix it with the white of eggs, isinglass, and a little yeast; well mix the materials, and spread the batter, thus formed, on even tin plates, and dry them on a stove, then cut them out for use. They may be coloured with vermilion or red-lead; or indigo, saffron, turmeric, gambouge, &c.

TANNING.

Tan, tannin, or the principle that effects the operation of the art of tanning, is usually produced from the bark of oak, chopped and ground in a mill into a coarse powder. M. Deyeux was the first chemist who ascertained and gave an account of the peculiar nature of tan. He pointed it out in his analysis of nut-galls, as a peculiar resinous substance, but without assigning to it a name. Seguin, who ranks high in France, as a chemist, and as one who has entered deeply into the principles of tanning, though not so much regarded by the tanners in England, engaged in a very extensive set of experiments on the art of tanning leather, during which he discovered that *tan* has the property of precipitating glue from its solutions in water, and also of combining with skins of animals. This led him to suppose it the essential constituent of the liquids employed for the purpose of tanning leather, and hence arose the names *tan*, *tannin*, and *tanning principle* given it by the French chemists. To M. Proust, however, we are indebted for the investigation of the nature and properties of tan, and of the methods by which it is obtained in a separate state. Much curious and important information has been obtained by the experiments of Sir Humphry Davy, on the constituent parts of astringent principles, and on their operation in the business of tanning, and to the papers of that gentleman, which we understand are founded on practice, we shall be chiefly indebted for the rules hereafter given, as guides to the English Tanner.

Tan exists in a great number of vegetable substances, but it may be procured most readily, and in the greatest purity from nut-galls and catechu. Nut-galls, are, as most of our readers know, excrescences formed on the leaves of the oak by the puncture of an insect which deposits its eggs upon them. The best are known by the name of Aleppo-galls, imported in large quantities into this country for the use of dyers, calico-printers, &c. They are hard like wood, round, often nodulated on the surface, of an olive-green colour, and of an excessively disagreeable taste. They are, in a measure, soluble in water, and what remains is tasteless, and possesses the properties of the fibre of wood. A very great proportion of water is necessary to carry off every thing soluble. It has been ascertained that one hundred and fifty English pints of water are necessary to carry off whatever is soluble in a pound troy-weight, of galls. The soluble part of nut-galls consists chiefly of five ingredients, viz. tan; extract; gallic-acid; mucilage; and lime: but tan constitutes more than two-thirds of the whole. Hence the importance of nut-galls, and oak-bark in the art of tanning, of which the following is a brief description.

Hides quickly become putrid when in a moist or wet state, but may be preserved for a great length of time by being perfectly dried, but then are hard like horn, and not fit for any useful purpose. These inconveniences are obviated by tanning, and they then take the name of leather. To tan a hide, is to saturate it with tannin, or the astringent principle of vegetables, and by that means, to render it incorruptible. We shall not here dwell upon the theories by which the operations and the effect of tanning have been explained; but shall content ourselves with observing that M. Seguin has shewn that the tannin unites itself with the gelatine which forms almost the whole of the hide, and that there thence results a new substance possessing properties altogether distinct. In order to prepare a hide for receiving the tan, it is necessary to begin by removing the hair, separating the adhering pieces of fat, &c. These preliminary operations are performed in the following manner:—

When the hides, which are to be tanned, are raw (in which

which state they are called green hides), they are put to steep in water, in order to clear them of the blood and filth they may have collected in the slaughter-house. They are left to soak in the water for some time, and if the hides are dry, they are steeped a longer time, sometimes for fourteen days; less in hot weather, or more in cold. They are drawn out once or twice to see if they are well softened. The neighbourhood and the command of water are necessary to these operations. Without that the hides cannot be prepared.

After the hides have been well softened they next proceed to cleanse or free them from the hair. With this intention several different methods are employed; that which is the oldest, and still most generally followed, consists in the application of lime. In all tanneries, pits are formed under-ground, having their sides lined with stone or brick, in which lime-stone is slacked so as to form milk of lime. These pits are divided into three kinds, according to the greater or less strength of the lime. The hides intended to be scoured are first put into the weakest of these pits, wherein they are allowed to remain until the hair readily yields to the touch. If this liquor be not sufficiently active, they are removed to the next in gradation. The time they are soaked is longer or shorter in proportion to the strength of the lime, the temperature of the air, and the nature of the hides. It has been proposed to substitute lime-water in place of the milk of lime. But, though the lime-water acts at first with sufficient strength, its action is not sufficiently permanent, and, in order to succeed in clearing the hides by this means, it is necessary to renew it occasionally; and in this way the hides may be prepared in a few days. In some tanneries, after they have been kept in the pits for a short time, they pile them up in a heap on the ground, in which state they are suffered to remain during eight days; after which they return them into the same pits from whence they were taken, and this process is repeated till the hair can be easily scraped off.

In many countries they mix a large quantity of ashes with the lime; but the only effect this mixture appears to produce is that of rendering the leather less consistent than when lime is solely employed. Many attribute the bad qualities of leather to the too great use of lime, which has a tendency to burn and render it brittle. Hence, in several well-conducted tanneries, in manufacturing leather for some particular uses, the employment of lime is carefully avoided. Hides may, indeed, be cleansed by subjecting them to an incipient fermentation, which may be produced in a variety of ways. But in whatever manner the first part of the operation has been conducted, as soon as it is perceived that the hair is in a fit state to be removed, it is scraped off, on a wooden horse, by means of a crooked knife, which is not so sharp in any part of its edge as to injure the hide, or, by a whet-stone. This operation is not only intended to remove the hair, but likewise the scurf and filth which collects on the skin at the root of the hair.

After removing the hair and filth, the next object is to free the hides from the adhesion of any part of the muscle, or fat, and to render them soft and pliant. Those which are intended for particular kinds of work, such as calves' skins for the upper leather of shoes, and neats' leather for shoulder-belts, do not require to be raised or swelled. As soon, therefore, as they are cleansed and freed from the flesh, &c. they are laid in a pit. The hides intended for the soles of shoes, and other strong leathers, are afterwards raised by means of processes which vary in different countries. When lime is employed, the operation is commenced by putting the cleansed skins into the weakest of the lime-pits, and afterwards passing them successively through the two others. They are kept about a week in each of the two weakest pits, and another in the strongest. During this operation care is taken to withdraw them, and pile them up in a heap, every two or three days, putting them again into the pit after it has been well stirred. Lime hardens the skin, and in those tanneries where it is used, the hides are put into a ley of pigeons' dung in order to soften them, and this process is termed graining. They are daily withdrawn from the ley, and laid up in a heap for half an hour. This operation is usually continued for ten or fifteen days. Sometimes also acid compositions are employed for raising the hides; and this operation is greatly accelerated by using the acids warm, as well as by the method practised in this country, of removing them from a weaker liquor into a stronger, until they be properly raised or swelled.

The skin being thus prepared, is next subjected to the operation of tanning; and to this purpose vegetable astringents are employed. Those vegetables answer best which contain the greatest portion of the astringent principle, now known under the name of tannin. Mr. Davy has demonstrated that caoutchouc or Japan earth, contains more of this principle than any other vegetable with which we are acquainted; but oak bark is the substance most commonly employed in our climates; for it is not only very abundant in Europe, but likewise contains much tannin. Every species of oak, however, does not supply us with bark of the same quality; the white oak is inferior to the green oak which grows in the south, while this in its turn yields in the value of its bark to that procured from the roots of the kermes-bearing oak, which is employed in southern climates for tanning strong leathers. But whatever kind of bark be employed, it is previously ground down to powder. The tan-pits are sometimes of a round, and at others of a square form, dug out to a considerable depth in the earth, and lined with wood or mason-work; their size being in proportion to the extent of the works. The method of tanning is different in different countries.

According to calculation, from five to six pounds of tan is required to each pound of strong leather; and one hundred weight of hides yields from fifty-two to fifty-six pounds of leather.

It

It appears that the operation of tanning is nothing more than combining the tannin, or astringent principle with the gelatin, which is the basis of the skin, and all the manipulations of the art are directed to effect or facilitate this combination. We will now detail another method chiefly taken from Mr. Davy's memoir on the subject.

After the skin has been cleaned, it is submitted to other operations before it is immersed in the tan liquor. According to Mr. Davy's account of the practices of the art, the large and thick hides which have undergone incipient putrefaction, are introduced for a short time into a strong infusion of oak bark, and after this they are acted on by water impregnated with a little sulphuric or acetic acid; in consequence of which they become harder and denser than before, and fitted after being tanned, for the purpose of forming the stouter kinds of sole leather. The lighter and thinner skins are treated in a different manner: they are macerated for some days in a ley formed from the infusion of pigeons' dung in water, which contains a little carbonate of ammonia; the skin is thus deprived of its elasticity, and becomes more soft.

The tanning liquor is prepared by infusing bruised oak bark in water; and skins are tanned by being successively immersed in such infusions, saturated in different degrees with the astringent principles of the bark. The first leys in which they are immersed are weak, but towards the completion of the process they are used as strong as possible; and in preparing stout sole leather, the skins are kept in an ooze, approaching to saturation, by means of layers of oak bark.

The infusion of oak bark, especially that obtained by the first maceration, contains principally tannin and extractive matter; the gallic acid, if present, as has been supposed, being at least in an inconsiderable proportion. In the course of the maceration of the skins in these liquors, the tannin combines gradually with the gelatin, which, in an organized form, principally constitutes the skin, and forms with it a compound insoluble in water, dense and impermeable to that fluid, while it possesses at the same time a certain degree of elasticity. The extractive matter also enters into the combination; for when skin in a large quantity has exerted its full action on a small quantity of infusion, it at length abstracts the whole dissolved matter, and renders it colourless. From this extractive matter colour is derived, and the skin may perhaps be rendered more dense.

It has been supposed, that the gallic acid frequently contained in vegetable astringents, facilitates the action of their tanning, in converting skin into leather. According to the theory of the operation, as given by Seguin, skin is gelatin in a hardened state from slight oxidizement; the gallic acid in some measure de-oxidizes it, and hence reduces it to that state in which it combines more easily with gelatin. There is little proof given, however, of this theory; and it appears sufficiently established, that the operation can be performed without the presence of this acid; and indeed in the tan liquor prepared by one maceration from oak bark it is scarcely discoverable, and, if it do exist in it, it is in intimate combination with the extractive matter.

The operation of tanning, as now described, requires a number of months, from the skins being successively and slowly introduced into infusions of different degrees of strength. Seguin, after his discovery of tannin, proposed to abridge the process by introducing the skins more speedily into strong infusions of the tanning substance; and in this way, according to the excellent report given on the art of tanning by Pelletiere and Lelivre, in which his method is fully described, the whole could be finished in about twenty days, and leather obtained equal in quality to that prepared by the old method. There is reason, however, to doubt of the superiority of this new method. Mr. Nicholson, in some observations on this subject, when a patent was taken out for Seguin's method in this country, stated, that from information acquired from the manufacturers, he found that they had previously been sufficiently acquainted with the powers of the strong tanning infusions; and that it had been even proposed to employ them so as to abridge the process. But the leather thus prepared was by no means equal to that prepared in the old method. The advantage of the slow and gradual process appears to be, that the whole substance of the skin is penetrated and equally changed; while in the more rapid method the external parts must be more acted on; and the texture probably will be more unequal. It appears also from Mr. Davy's experiments, to combine with a larger quantity of the extractive matter contained in the astringent infusion; and hence too the advantage of the immersions in the weak liquors, as these contain more of this than the strong infusions. It must be confessed, however, that for any thing theory can discover, the common process appears to be unnecessarily protracted, and some advantage might probably be derived from adopting some of the manipulations of Seguin.

The skin in drying increases in weight from the fixation of the vegetable matter: the quantity of this seldom exceeds one-third of its weight. The increase is greater, according to Mr. Davy's experiments from quick than from slow tanning. In the latter, he supposes more of the extractive matter enters into combination, and this weakening the attraction of the skin to tannin, less of it is absorbed, and less vegetable matter on the whole enters into the composition of the leather. Probably also, in the slow process, more of the animal matter is removed. Other substances are used in tanning, as the bark of the willow, elm, and other trees, and, as we have seen, galls and catechu. The leather prepared from these varies in colour, and in some other external qualities.

Catechu, or terra Japonica, as it is sometimes called, is a substance obtained by decoction and evaporation from a species of *Mimosa*, which abounds in India. There

There are two varieties of it; one from Bombay, and the other from Bengal. This substance is found to consist chiefly of tan, combined with a peculiar species of extract. Tan is chiefly found in the bark of trees, but it has been obtained from the sap, the wood, and even the leaves. It varies in quantity according to the season of the year, and it likewise varies with the age and size of the trees. The greatest proportion of tan is contained in the inner barks. The epidermis usually contains none. The following table exhibits the proportion of solid matter extracted by water from different vegetable substances, and the quantity of tan contained in that solid matter, as ascertained by the experiments of Mr. Davy:

One Ounce of	Solid Matter.	Tan.
White inner bark of old oak, contains	108	72
——— ——— young oak	111	77
——— ——— Spanish chesnut	89	63
——— ——— Leicester willow	117	72
Middle bark of oak	43	19
——— Spanish chesnut	41	14
——— Leicester willow	34	16
Entire bark of oak	61	29
——— Spanish chesnut	53	21
——— Leicester willow	71	33
Sicilian sumach	165	78
Malaga sumach	156	79
Bombay catechu	—	261
Bengal catechu	—	231
Nut-galls	180	127

Of Tawing, Leather-dressing and Dyeing, and other Processes.—The dressing and preparing of the skins of lambs, sheep, goats, and other thin hides, though in many particulars closely resembling the method used with the thick cow and ox hides, forms a totally distinct branch of business, and is one in which a good deal of practical skill and nicety of manipulation are required to succeed perfectly. The processes are various according to the article required, and this branch of the manufacture supplies the immense demand of white and dyed leather for gloves, the morocco leather of different colours and qualities for coach-linings, book-binding, pocket-books, and thin leather for an infinite number of smaller purposes. Of these the white leather alone is not tanned but finished by the process of tawing, the coloured leather receives always a tanning independently of the other dyeing materials. The previous preparation of each, or that in which the skin is thoroughly cleansed and reduced to the state of simple membrane in which it is called pelt, is essentially the same whether for tawing or dyeing. It is thus performed at Bermondsey, near London, a place long celebrated for all branches of the leather business.

By far the greater number of the skins are imported: if lambs, they are thus prepared; the skins are soaked for a time in water, to cleanse them from any loose dirt and blood, and put upon the beam commonly used for the purpose, which is a half cylinder of wood covered with leather, and scraped on the flesh side with the semicircular blunt knife with two handles, used in this operation. They are then covered with a coat of lime of the consistence of paint, on the flesh side, and hung up in considerable numbers in a small close room heated by flues, where they remain to putrefy for a given time. During this process a thick slime works up to the surface of the skin, by which the regularity of the process is ascertained, and the wool is loosed so that it readily comes off with a slight pull. Each skin is then returned to the beam, the wool taken off, and all the lime worked off with the knife, and the rough edges pared away. The skin is then put into a pit filled with lime-water and kept there from two to six weeks, according to the nature of the skin, which has the effect of checking the further putrefaction, and produces a very remarkable hardening and thickening of its substance, and probably also it detaches a further portion of the slime. The skin is again well worked, and much of its substance pared down, and all inequalities smoothed with the knife. Pains and judgment are required in these operations on the one hand not to endanger the substance of the skin by the putrefaction, and on the other hand to work out every particle of the lime, of which the least if retained will prevent the skin from dressing well in the subsequent processes, and from taking the dye uniformly and well. The skin is then again softened and freed from the lime. All the thickening produced by the lime is thus removed, and the skin is now highly purified, and is a thin extensible white membrane called in this state a pelt, and is fit for any subsequent operation of tawing or dyeing, or oil-dressing, or shammoying.

The method of bringing kid and goats' skins to the state of pelt is nearly the same as for lambs, except that the lining is used before the hair is taken off, the hair being of but little importance, and only sold to the plasterers; but the lambs' wool, which is more valuable, would be greatly injured by the lime. Kids' skins will take a longer time in tanning than lambs'.

If the pelts are to be tawed they are put into a solution of alum and salt in warm water, in the proportion of three pounds of alum and four pounds of salt to every 120 middle sized skins, and worked therein till they have absorbed a sufficient quantity. This again gives the skin a remarkable degree of thickness and toughness.

The skins are now taken out and washed in water, and then again put into a vat of bran and water and allowed to ferment, till much of the alum and salt is got out and the unusual thickening produced by it is for the most part reduced. They are then taken to a room with a stove in the middle, and stretched on hooks, and kept there till fully dry. The skins are now converted into a tough, flexible, and quite white leather; but to give them a glossy finish, and to take off the harshness of the feel still remaining, they are again soaked in water, and put into a large pail containing the yolks of

eggs

eggs beat up with water. Here the skins are trodden for a long time, by which they so imbibe the substance of the egg that the liquor above them is rendered almost perfectly limpid; after which they are hung up in a loft to dry, and finished by glossing with a warm iron.

The essential difference, therefore, between tanning and tawing is, that in the former case the pelt is combined with tan and other vegetable matter, and in the latter with something that it imbibes from the alum and salt (possibly alumine); and which is never again extracted by the subsequent washing and branning.

The Morocco leather, as it is called, prepared from sheep-skins chiefly, and used so largely for coach-linings, pocket-books, and the best kind of book-binding, is thus made: the skin, cleansed and worked in the way already described, is taken from the lime-water, and the thickening brought down, not by bran liquor as in tawing, but by a bath of dogs' or pigeons' dung diffused in water, where it remains till suppled, and till the lime is quite got out and it becomes a perfectly white clean pelt. If intended to be dyed red it is then sewed up very tight in the form of a sack with the grain side outwards, and is immersed in a cochineal bath of a warmth just equal to what the hand can support, and is worked about for a sufficient time till it is uniformly dyed. The sack is then put into a large vat containing sumach infused in warm water, and kept for some hours till it is sufficiently tanned.

The skins intended to be black, or any colour but red, are merely sumached without any previous dyeing. After some further preparation, the colour of the red skins being finished with a weak bath of saffron, the skins when dry are grained and polished in the following way; they are stretched very tight upon a smooth inclined board, and rubbed over with a little oil. Those intended for black leather are previously rubbed over with an iron liquor, which uniting with the gallic acid of the sumach, instantly strikes a deep and uniform black. They are then rubbed by hand with a ball of glass with much manual labour, which polishes them and makes them very firm and compact. Lastly, the graining or ribbed surface by which this kind of leather is distinguished is given by rubbing the leather very strongly with a ball of box-wood; round the centre of which a number of small equidistant parallel grooves are cut; forming an equal number of narrow ridges, the friction of which gives the leather the desired inequality of surface.

The process for the real Morocco leather, as prepared from goat-skins at Fez and Tetuan, is thus described by M. Broussonet. The skins are first cleansed, the hair taken off, limed, and reduced with bran nearly in the way already described for the English morocco leather. After coming from the bran they are thrown into a second bath made of white figs mixed with water, which is thereby rendered slimy and fermentable. In this bath the skins remain four or five days, when they are thoroughly salted with sal-gem, or rock salt alone, after which they are fit to receive the dye, which for the red is cochineal and alum, and for the yellow, pomegranate bark and alum. The skins are then tanned, dressed, suppled with a little oil, and dried.

Much excellent leather, and of various colours, is manufactured in different parts of Russia; of which, the processes are given in Mr. Tooke's "View of the Russian Empire," Vol. III. The saffian, or maroquin, which is prepared largely at Astracan, is manufactured only from the skins of goats and bucks; the usual colours of these are red and yellow. The shagreen, which is also manufactured at Astracan, consists of hides of horses and asses; but of these only a small part is used, cut from the crupper-line along the back about thirty-four inches upon the crupper, and twenty-eight along the back. The chief dyes of shagreen are green, blue, and black.

Various processes have been invented to render leather for shoes and boots water-tight, which is effected by an additional dressing with an oily or resinous matter: the following recipe is said to be effectual. One pound of linseed-oil; half a pound of mutton suet; six ounces of bees-wax, and four of resin, are to be melted, thoroughly incorporated, and applied, while warm, to the upper-leather and the soles.

TIN-PLATE-WORKING.

On the affinity which there is between tin and iron is founded the art of forming what is commonly called tin-plates, which is, properly, tinned iron, or as it is denominated in Scotland, and also on the Continent, *white iron*. The process in manufacturing these plates is simply this; thin plates of malleable iron thoroughly cleared from all rust or oxyde, are dipped into a vessel of melted tin, the surface of which fluid metal is protected from oxydizement by the air, by a thin layer of melted tallow, the tin unites with the iron at each surface, but whether the two metals actually combine is not yet ascertained. The iron thus acquires a white colour, is rendered less liable to rust, and its ductility is scarcely at all impaired; hence the plates can be easily

easily bent; and from the alloy of tin at the surface can be also easily worked. Iron-plates when tinned over, and which are very thin, have been denominated latten. Of the manufacture of these we have an account in the Philosophical Transactions of the Royal Society, and from which we shall extract some particulars. Plates of iron being prepared of a proper thickness, are smoothed by rusting them in an acid liquor, as common water made eager with rye; with this liquor they fill certain troughs, and then put in the plates, which they turn once or twice a day that they may be equally rusted over; after this, they are taken out and well scowered with sand, and to prevent their rusting again are immediately plunged into pure water, in which they are to be left till the instant they are to be tinned or blanched, the manner of doing which is this: they flux the tin in a large iron crucible, which has the figure of an oblong pyramid with four faces, of which two opposite ones are less than the two others. The crucible is heated only from below, its upper part being luted with the furnace all round. The crucible is always deeper than the plates which are to be tinned are long; they always put them in downright, and the tin ought to swim over them; to this purpose artificers of different trades prepare plates of different shapes, though M. Reaumur thinks them all exceptionable. But the Germans use no sort of preparation of the iron to make it receive the tin, more than the keeping it always steeped in water till the time only when the tin is melted in the crucible, they cover it with a layer of a sort of suet, which is usually two inches thick, and the plate must pass through this before it can come to the melted tin. The first use of this covering is to keep the tin from burning; for if any part should take fire the suet would soon moisten it and reduce it to its primitive state again. The blanchers say, this suet is a compounded matter; it is indeed of a black colour, but M. Reaumur supposed that to be only an artifice to make it a secret, and that it is only coloured with soot or the smoke of a chimney, but he found it true so far that the common unprepared suet was not sufficient, for after several attempts, there was always something wanting to render the success of the operation certain. The whole secret of blanching, therefore, was found to lie in the preparation of this suet, and this he discovered at length to consist in the first frying and burning it. This simple operation not only gives it the colour, but puts it into a condition to give the iron a disposition to be tinned, which it does surprisingly. The melted tin must also have a certain degree of heat, for if it is not hot enough, it will not stick to the iron: and if it is too hot it will cover it with too thin a coat, and the plates will have several colours, as red, blue, and purple, and upon the whole have a cast of yellow. To prevent this, by knowing when the fire has a proper degree of heat, they might try with small pieces of iron; but in general, use teaches them to know the degree, and they put in the iron when the tin is at a different standard of heat, according as they would give it a thicker or a thinner coat. Sometimes also they give the plates a double layer, as they would have them very thickly covered. This they do by dipping them into the tin, when very hot, the first time; and when less hot the second. The tin which is to give the second coat must be fresh covered with suet, and that with the common suet, not the prepared.

Tin-plates are often manufactured in a different way: the iron in bars, or plates is cased over with tin, and then drawn out by means of rolling-mills. In 1681 tin-plates were made in England by a person named Andrew Yarranton, who was sent into Bohemia to learn the art, but it was not brought into perfection, for more than fifty years, and since the middle of the last century, it has been carried on in these islands in so perfect a manner, that scarcely any have been imported from the continent. Our plates are of a finer gloss, or coat, than those made beyond sea, the latter being chiefly hammered, but ours, according to the plan of which we are now speaking, are always drawn out by the rolling-mill.

The tin-plate worker, a trade well known in London, and all large towns, receives his tin-plate in sheets, and it is his business to form them into all the various articles of domestic use, which are known to every body. The principal instruments that he makes use of are a large pair of fixed shears, to cut the tin to the proper size and shape: a polished anvil, and hammers of various kinds, some of which are highly polished on the face. The joints of his work are made with solder, which he makes himself, and which is a composition of equal parts of tin and lead, that the workman causes to unite with the tin-plate, or tinned-iron, by means of rosin. The two principal wholesale houses in London, are those of Jones and Taylor, in Tottenham-Court-Road, and of Howard and Co. in Old-Street-Road. These and other wholesale traders have constantly travellers in various parts of the kingdom; and as they cannot carry the articles of their trade, in saddle-bags, like many other manufacturers, they take with them drawings of all works of taste, in their line of business.

Tin, in blocks, resemble silver, but it is of a darker hue; it is also much softer, less elastic and sonorous, than any other metal excepting lead: it is most readily extended, and melts with a lower heat than all other metals. When tin is made is made very hot, it will break with a blow. In the state of ore, it is found mixed with arsenic. The chief tin mines in the known world are those of Cornwall; and it is a fact well ascertained, that the Phœnicians visited these islands, for the purpose of getting tin from our ancestors, several centuries before the Christian æra. In tracing the history of the Cornwall mines, we find that they produced very little in the reign of king John, but the right, at that period was wholly vested in the sovereign, as Earl of Cornwall. Their value has fluctuated at different periods; of late years they have produced to the value of a hundred and fifty, or two hundred thousand pounds. The Prince Regent, as Duke of Cornwall, receives four shillings

upon

upon every hundred weight of what is called *coined* white tin, which sometimes amount to ten or twelvé thousand a year: the proprietors of the soil have one-sixth, and the rest goes to the adventurers in the mine, who are at the whole charge of working. As the tin is to be thus divided, or rather its real value ascertained, it is stamped and worked at the mill, and it is then carried under the name of block-tin to the melting-house, where it is run into blocks, and thence carried to the coinage town. The coinage towns are Leskard, Lestwithiel, Truro, Helston, and Penzance, being the most convenient parts of the county for the miners.

We may observe that from the affinity between tin and copper, a thin layer of the former metal can be easily applied to the surface of the latter; and this practice of tinning, as it is named, is often employed to prevent the erosion or rusting of copper-vessels, and the noxious impregnation which they would of course communicate to liquors kept in them. The surface of the copper is polished so as to be quite bright: sal-ammoniac is applied to it when hot, by which the oxidation appears to be prevented; or pitch is sometimes used for the same purpose; the melted tin, or what is often substituted, on account of its hardness being greater than that of pure tin, an alloy of tin and lead, is applied to the surface of the copper, to which it adheres.

TURNING.

Turning is a mechanical operation, for shaping various hard substances, as wood or metal, into a round or oval figure, in a machine called a lathe. The operation differs very essentially from most others, in the circumstance, that the matter to be operated upon is put in motion by the machine, and is wrought by means of edged tools presented to it, and held fast; whilst in most others, the work is fixed, and the tool put in motion by the workman.

In turning, the work is caused to revolve upon a stationary straight line, as an axis, while an edge tool set steady to the outside of the substance in a circumvolution thereof, cuts off all the parts which lie farther off the axis, and makes the outside of that substance concentric to the axis. In this case any section of the work, made perpendicularly to the axis, will be of a circular figure; but there are methods of turning ellipses, and various other curves, which are known by the name of engine-turning.

When compared with many other mechanical operations, the art of turning may be considered as perfect in the accuracy and expedition of the work, which is produced, and that independently of any extraordinary skill or dexterity of the workman; the lathe is therefore resorted to by mechanics to perform every work it is capable of, and these are so numerous as to demand in preference to other mechanic operations, a minute detail.

Lathes are made in a great variety of forms, and put in motion by different means, they are called *center lathes* where the work is supported at both ends; *mandrel, spindle,* or *chuck* lathes when the work is fixed at the projecting extremity of a spindle. From different methods of putting them in motion, they are called *pole lathes,* and hand *wheel-lathes,* or foot *wheel-lathes;* for very powerful works they are turned by horses, steam engines, or water-mills. The lathes used by wood turners are generally made of wood, in a simple form, and are called bed-lathes, the same kind will serve for turning iron, or steel, but the best work in metal is always done in iron lathes, which are usually made with a triangular bar, and are called *bar-lathes.* Small ones for the use of watch-makers, are called *turn-benches,* and *turns,* but there is in fact no proper distinction between these and the centre-lathes, except in regard to size, and that they are made of iron instead of wood.

The Centre-lathe is now very little used, *but by* country turners, to make trifling articles of household furniture in soft wood, as table-legs, stair-case rails, &c. it consists of the following parts, 1st. the *bed,* which is composed of two-beams bolted together at a small distance asunder, and parallel to each other, it is supported horizontally on legs at the ends, and forms the support of the whole; the *groove,* is the narrow opening between the two halves, or chucks of the bed, to receive the tenons of the *puppets,* which are two short upright posts fastened down upon the bed at any place by means of wedges, driven through mortises in the tenon of the puppets beneath the bed; one of the puppets has a *pike* or pin of iron fixed into it, and the other one has at the same level the *centre-screw,* working through a nut fastened in the puppet, both the screw and the pike have sharp points made of steel, and hardened and tempered, that they may not wear away; there must be exactly opposite, and in a line with each other, the piece of work which is to be turned, suppose for instance a pole

a pole of wood, is supported by its ends, between the points of the pike and the screw, that it may turn round freely, and the screw is screwed up, till it has no shake, the puppets can be placed at any distance asunder according to the length.

The *rest* is a rail or bar, extending from one puppet to the other, for the support of the tool; it lays in hooks projecting from the faces of the puppets; the work is put in motion by means of the *treadle*, which is worked by the turner's foot, the string or cat-gut is fastened to the treadle, and passing two or three turns round the work, it is fastened to the end of an elastic pole, fixed to the ceiling over the turner's head: now as the turner presses the treadle down by his foot, the string turns the work round, and a sharp chisel or gouge, being held against the wood upon the rest, will cut the wood to a circular form. When he has brought the treadle to the ground, he releases the weight of his foot, and the elasticity of the pole draws up the treadles turning the work back again; during which retrograde motion he withdraws the chisel from the work, as it would not cut in this direction through it, and might impede the motion of the wood; and the pole is fastened to the ceiling of the room where the lathe is placed by a pin, upon which it can be turned about as a centre, and it rests upon a horizontal bar fixed at some distance from the centre; it is placed in a position nearly perpendicular to the axis of the work, so that when it is turned upon its centre pin, the string at the other end may be brought over any part of the length of the work where it will be most convenient for the turner to have the string put round it: in the same manner the end of the treadle is placed, with one end over a centre pin in the floor, that its opposite end may be moved under the work to the proper place for the string. It is held in this position while moving up and down, by a second treadle, perpendicular to the first which moves on a loose centre on the floor at one end, and the other is perforated with a number of holes to receive a pin fixed in the first treadle, and thus to confine the treadle to move up and down under any place it is set to: the end of the principal treadle is turned in the lathe and made like a pulley, to hold the line or string which is wound upon it, and the turner winds the string on or off this end of the treadle, to adjust its length to the diameter of the work round which the string passes; the string is fastened to the end of the spring pole in a similar manner. The workman stands or is seated before his lathe, having one of his feet on the treadle to give the motion; it must be very moderate and equal: he places his tool on the rest, and approaches the head of it gently to the piece, performing his work gradually without leaving any ridges, and when he meets with a knot, he must go on still more gently, otherwise he would be in danger both of splitting his work, and breaking the edge of his tool. For turning light-work, a bow, such as is used for shooting arrows, is suspended by its middle over the lathe, the string is then tied to the middle of the bow-string in lieu of the pole, and acts in the same manner. The continued rotatory motion given by a wheel, is so much superior for turning to the reciprocating motion of a treadle and string, that regular turners seldom make use of the latter, yet the simplicity of the whole is a great recommendation, especially among country workmen, who are not so careful of their time, as in the towns where competition obliges every one to use the best and quickest means of dispatching his work.

The common centre lathe becomes a powerful machine, when worked by means of a large wheel, turned by one or more labourers; the wheel should be heavy that its momentum may be sufficient to overcome any trifling obstacle in the work, and the frame in which it is mounted must be of sufficient weight to stand steady, and not be liable to move by the exertions of the man turning it. An endless line is used to communicate the motion of the wheel to the work; it passes round a groove in the circumference of the wheel, and after crossing like a figure of eight, goes round a small pulley fixed upon the work; by this means when the great wheel is turned, it gives a rapid rotatory motion to the matter to be turned, and with a much greater power than can be obtained from the treadle, with the additional advantage of the work turning always the same way round, so that the turner has no need to take his tool off the work; the small pulley is perforated with a square hole, to receive a square made on the end of the work, and the turner has many different pulleys, each with a different sized hole through it, to suit work of different diameters; but there is an inconvenience attending this method, for if the four corners of the square, on which the pulley is fitted, be not all equally distant from the centre of the work, the pulley will not turn round truly, and the band will be liable to slip round upon it. To obviate this, the pulley, *Fig.*13, Turning, *Pl.* II, is often used; it has a square hole through it to receive the work, and is made to fit upon it by means of four screws *a a a a* passing through a part of the wood by the side of the pulley, and their point pressing into the work: in this manner one or two pulleys can be made to serve work of any dimensions and can always be set truly upon it: it has, as shewn in the edge view, two different sized grooves, A B, in either of which the band may be worked when required.

There is a kind of centre lathe, which is generally employed by Millwrights, and Iron-founders, in turning heavy metal work, such as the gudgeons of mill-shafts, rollers for sugar or rolling-mills, pump-rods, which are to pass through stuffing boxes, or in short, any work which will admit of having both its ends supported on centres: it is in many respects similar to that we have described, but is adapted to give a continued rotatory motion to the work; it has legs which support it from the floor, and the bed is formed by two parallel beams or cheeks bolted to the legs: one of the legs stands up above the bed to support the main, or left hand centre point, instead of having a puppet on purpose. The centre pin is fastened into it, by a nut and

screw behind, and upon this pin two wooden pulleys are fitted side by side, close to each other, so that they appear but one: either of those at pleasure is caused to turn round by means of an endless strap, going round a drum extending over head, or under the floor, and which is turned by horses or a steam engine; the strap being only the breadth of one of the pulleys, will turn but one of them at a time, but it can easily be shifted from one to the other at pleasure, and then the other will stand still; the front one of these pulleys gives motion to the work.

The back puppet is fixed upon the bed of the lathe, by a tenon projecting downwards, and entering the space between the two chucks of the bed; it is fixed at any place by means of a screw bolt, which passes down through the puppet, and goes through a piece of iron, which takes its bearing on the under side of the bed; a nut *f* is fitted on this screw, and thereby the whole puppet can be drawn down upon the cheeks, so firmly that it will not move by any strain the work may occasion; the back puppet carries the back centre screw, which has a steel point to support the work.

The rest of this kind of lathe is made of iron in the usual manner of bed lathes, as is represented at *Fig.* 3, of *Plate* I; its construction will be detailed when we describe that plate.

The work is turned about in this lathe by means of an iron pin, projecting some inches from the flat surface of the front pulley, which, as before mentioned, is fitted on the centre point; a piece of iron called a driver (*see Fig.* 5. *Plate* II) is screwed upon the work near its left hand end, so as to project perpendicularly from it, and the pin, in the pulley, intercepts this as it turns, carrying the work round with it.

The other pulley which is fitted on the centre pin, is only of use, when the lathe is wanted to stand still, in the same manner as the live and dead pulleys used in cotton-mills. When the workman wishes to put the lathe in motion, he presses the handle of his tool, or any other smooth piece of wood, against the edge of the endless strap while it is in motion, and pushes it towards the front pulley; in a very short time the strap will get completely on the pulley, and shift itself to a fresh place on the drum corresponding to the pulley: this causes the pulley to turn round, and by the pin pushing round the end of the driver screwed on the work, communicates its motion to the work to be turned. When he wishes the motion to cease, for the purpose of examining his work, he pushes the strap back again on to the other pulley, which has no communication with the work as it slips freely on the centre pin; the driver, as shewn by the figure, is simply an iron ring, having a screw tapped through one side of it, to pinch the work so fast, as to prevent its slipping. The side opposite the screw should be angular, that it may fit any sized work; this driver may be fixed on either end of the work while the other is turning, but when it is necessary to fix the driver on that part of the work which is finished, the end of the screw is apt to pinch and bruise it; it is therefore proper to use the driver, *Fig.* 6, composed of two bars of iron screwed together by two screws, passing through one bar tapped into the other; both bars are somewhat hollowed out in the middle that they may encompass the work. If this should be found to injure the work, a piece of sheet-lead wrapped round it before the driver is put on, will prevent the possibility of its damaging the work, and if the screws of the driver are drawn very tight, it will carry the work about with sufficient force to bear turning.

The manner of mounting and giving motion to a piece of metal work in the centre lathe is this: the back puppet is first fastened on the bed of the lathe at the proper length to receive the work, the workman then places one of its ends against the points of the front centre, with the point as near to the centre of the work as he can guess; he then brings the centre of the other end of the work opposite the point of the centre screw, and screws it up so as to hold the work just tight enough, to prevent its falling down. In this state by turning it round with one hand, while he holds a piece of chalk against it with the other, he finds whether it is pitched nearly concentric on the points; and if it varies much at any points, he turns back the screw and tries again, observing to shift the centre point nearer towards that side which appears to project farthest in revolving, and therefore gets marked by the chalk. When he has found the true centre, he screws up the point so hard that it may mark the end of the work; then taking the work out of the lathe, he punches or drills holes in the ends where the screw and centre points have marked, and when the work is returned into the lathe it will run nearly concentric; the driver being screwed fast on either end of the work as is most convenient, the work will be turned round by the pin projecting from the pulley as before described; the turning of heavy iron work, for which these lathes are used, is performed by various tools chiefly called hooks, but these will be farther described.

The centre lathe will perform any kind of work which can be turned upon centres made in the ends of it, but a great portion of the articles which are formed in the lathe must have one of their ends at liberty, to be operated upon while they are turning, as cups, boxes, and all kinds of hollow articles; these are turned in

The foot lathe with mandril and collar.—A lathe of this kind serves equally well for centre work; therefore if the professed turner is without a mandril lathe, one of these, constructed in the simplest and most economical manner, and chiefly of wood, that the artificer may be enabled to make it himself, is shewn in *Pl.* I, of TURNING. It is put in motion by a foot-wheel and treadle, so that the turner has both his hands at liberty for directing the tools. *A*, is the bed of the lathe, consisting of two beams or cheeks fixed parallel to each other, and leaving a small space between them, as shewn in *Fig.* 3, and at *o o*, *Fig.* 4. The bed is supported by three upright legs, as shewn in the figure; one of these projects up above the bed a sufficient height

to

to form one of the puppets C, for the support of the extremity of the spindle or mandril *e* F; the other end is supported in a collar fixed in an iron standard or puppet B, which is screwed down upon the bed by two bolts marked *t t;* this standard is shewn separately in *Fig.* 4. The back puppet D has a tenon which is received through the bed, and a wedge *s* put through it beneath the bed, by which it can be fastened at any place; *f* is the back centre pin, fitted through the puppet, and *g* is a screw situated behind it, to advance and keep it up to its work. The mandril is turned round by a band of catgut passing round the pulley *c*, and also round the large foot-wheel G, which is made of cast iron, and fixed on the end of the axis H; this is bent as in the figure, to form two cranks; united by two iron links to the treadle I, on which the workman presses his foot; this treadle is affixed by two short boards to an axis on which the treadle I moves. The wheel G is of considerable weight in the rim, and being wedged fast on the axis, turns round with it; it is the momentum of this wheel that continues to turn the work while the crank and treadle are rising, and consequently while the workman exerts no power upon them. When the crank has passed the vertical position, and begins to descend, he presses his foot upon the treadle, to give the wheel a sufficient impetus to continue its motion until it arrives at the same position again.

The length of the iron links which connect the cranks with the treadle I, must be such, that when the cranks are at the lowest, the board I of the treadle to which the links are hooked, should hang about two or three inches from the floor. The turner gives the wheel a small turn with his hands, till the crank rise to the highest and pass a little beyond it, then by a quick tread he brings the cranks down again, putting the wheel in motion with a velocity that will carry it several revolutions; he must observe to begin his next tread just when the cranks pass the highest point, and then it will continue running the same way, with a tolerably regular motion, if he is punctual in the time of his treads.

The rest F which supports the tool while it is in the act of turning, is made of iron, as shewn in *Fig.* 3: it is supported on the bed of the lathe by its foot, which is divided with a groove in the manner of a fork, to receive a screw bolt going down through the lathe bed, and fastening it at any place along them by a thumb-nut; the groove in the foot is for the purpose of allowing the rest to be moved to and from the centre of the lathe, to adjust it to the diameter of the work which is turning. The height of the rest is a matter of some importance in turning, and for some work it should be fixed higher than others; therefore the shank of the cross piece, or T, upon which the tool is laid, is received into a socket in the foot of F, and can be held at any height by a screw. As the socket is cylindrical, the edge of the rest can be placed inclined to the axis of the work, when turning cones, or other similar work; though the same purpose may be accomplished by the screw which holds the foot of the rest down to the bed of the lathe, admitting it to stand in an oblique direction.

The mandril or spindle is the most important part of the lathe; it is made of iron, in the manner shewn at *Fig.* 2, but the two extremities are of steel, which are hardened after being turned and finished; the small end has a hole made in it to receive the point of a screw, which, as shewn at *e*, *Fig.* 1, supports the end of it; the other end of the mandril is made larger, and has a hole within it cut with a female screw, for the purpose of fixing on the various chucks by which the work is turned; the outside surface of this end is turned extremely true, and is fitted in a brass collar at the top of the standard B, as shewn in *Fig.* 4; here *o o* represent the sections of the two cheeks of the bed, *q* one of the bolts marked *t*, *Fig.* 1, which fasten the standard down, this bolt goes through a piece of iron, *r*, situated beneath the bed. In the top of the standard is a square hole for the reception of two pieces or dies of brass, *h h*, which include the mandril between them; these are kept in their places by a piece of iron, *i*, fastened down by screws, *l l*, and *m* is a screw tapped through this, which presses the two dies together, and thus adjusts them to receive the neck of the mandril without any shake; the screw which supports the other extremity of the mandril fits in two iron or brass nuts, which are let into the back and front of the wooden puppet C, and by turning this, the mandril can be adjusted to run very correctly in length; to prevent the screw from turning back when the lathe is in motion, a nut is placed on the screw outside of the puppet, and after the screw is turned by its head to fit and hold up the mandrel, the nut is screwed firmly against the nut which is let into the outside of the puppet; this causes such a pressure upon the threads of the screw, that it is in no danger of turning back, as it would otherwise be liable to do with rough work.

The mandril by this means runs very steadily and accurately in its bearings, and it is plain that any piece of work being firmly attached to the end of it, by means of the screw before mentioned, may be turned by a tool held over the rest, in the same manner as if it was mounted between centres, but with the advantage that it be turned at the end, to make hollow work when required. The foot wheel causes the mandril to revolve very rapidly, so that it will perform its work very quick, and the workman must acquire a habit of standing steady before his work, that he does not give his whole body a motion when his foot rises and falls with the treadle I.

Turning Tools.—The tools which are generally used for turning wood and metal, are shewn in *Fig.* 5 to 21; they are fixed in long handles, and the turner holds them firmly down upon the rest, steadying them by placing the end of the long handle under his arm; at least this is the case with several of the principal of the tools which are most used; they are as follows:

Fig. 5. A gouge chiefly used for soft wood, for reducing it speedily to shape; the blade of this tool is formed

formed nearly half round to an edge, and the two extreme ends of this edge are a little sloped off, in the manner of an apple-scoop, that the middle part of the edge may cut away the prominences which are not concentric with the axis, and it has no corners which would catch and get fast in the rough wood; the hollow part is whetted upon a piece of Turkey stone, made with a convex edge for the purpose; the outside is whetted upon a common flat Turkey stone, turning it round, that all parts of the convex edge may successively be sharpened. In turning, the gouge must be held with an inclination, and the handle considerably depressed, so that the bevil or outside of the edge of the gouge may come very nearly in the tangent to the circumference of the work, and the cutting edge is above the axis.

Chisels, *Figs.* 13, 16 and 21, are used upon wood, after the gouge has reduced it to proper dimensions, to smooth and finish; they are not like carpenters' chisels, made flat on one side and bevelled upon the other, but are bevelled on both the flat sides, so that the edge is in the middle of the tool, and either side may be indifferently applied to the work; they are ground up and sharpened on the oil-stone to a keen edge. In using the chisel, the rest is raised considerably above the centre of the work, so as to be nearly on a level with the top of it, and the cutting edge must stand oblique to the axis of the cylinder, so as to prevent either angle from running into the work; for this purpose some have inclined edges, as *Fig.* 16. The chisel ought to be traversed along the work gradually, but not too fast, otherwise it will leave a roughness on the surface.

Fig. 6 is a graver; this tool is used for roughing-out metal, and smaller ones are used for finishing metal work, for which they are well adapted, as either the point or one of its edges may be used indifferently.

Fig. 7. A chisel with a round end, for turning hollow mouldings in wood.

Fig. 8. Another round edged chisel bent sideways; it is used for turning hollow work, or forming mouldings at the end of any work which is turning round in the lathe.

Fig. 9. A hook tool, with an edge formed at the end of the hook, that it may be applied to bore or enlarge the inside of a hollow piece of work when it is held in a chuck, or for turning hollow spheres.

Fig. 10. The pointed grooving tool is an angular pointed chisel, for turning grooves in any piece of work, or for making flat shoulders, by using its edges like a chisel.

Fig. 11, is a chisel sharp at its edges like a knife; it is used for turning the inside of hollow work, or deep grooves in any work.

Fig. 12, is a hooked tool with an edge upon the inclined side; it is used for turning hollow cones which are largest inside.

Figs. 14 and 15, are a pair of male and female screw tools for cutting male and female screws, by a method which we shall describe at length.

Fig. 18, is a knife or side tool, with an edge on the right hand side. It is used for turning the left hand side of a shoulder, or flat side of any work; it is also used for turning the cavities of hollow cylinders, or those hollows which have only one internal angle for turning both the bottom and the side; for this purpose the tool is made to cut both by its end and side edges, and these two cutting edges form an angle with each other rather acute. This tool must be held on a level with the axis of the work, as all inside tools are.

Fig. 17, a left-hand side tool; is not used for internal work, but for turning the right-hand side of a shoulder, or upon the left side of convex surfaces, such as spheres, torus, mouldings, ovolos, &c. The angle is upon the contrary side of this tool to the other. Left-side tools are made to various widths and sizes.

Fig. 19. A side tool with a curved edge for turning inside work.

Fig. 20. A narrow tool with a point, and an edge on each side of it some distance from it; it is called a parting tool, and is used to cut or part off a piece of wood when in the lathe.

Fig. 22. A pair of callipers to measure the size of the work.

Fig. 23. A large pair of the same kind, but provided with an arch and a screw, to fasten the points when opened to any certain distance.

Fig. 24. A pair of in and out callipers, one end for measuring the diameter of outside work, and the other for measuring the diameter of inside work. The two ends are equally distant from the centre, so that they always open to the same extent, and have an arch to fix them at any place; it is of use when the turner wishes to turn a cylinder or pin to fit exactly into a hollow cylinder already made; to do this the size of the hollow cylinder is measured with the lower end of the callipers, then the upper end will be 'ready opened to the proper extent to turn a cylinder which will exactly fit the other.

Fig. 25. A depth gauge, consisting of a ruler, which is applied across the face or end of a piece of hollow work, and a slip of steel sliding through it; the end of this is the gauge for the depth of any hollow work which is turning.

Fig. 26. A pair of callipers with a straight and a curved leg, to measure the thickness of the sides of a hollow box or cup.

These are the principal tools which are required for wood-turning. The turner must likewise be provided with a grindstone and an oil or turkey stone to sharpen his tools. For fixing his work in the lathe he must have a great assortment of chucks; these are blocks of wood which have a screw projecting from them, by which any one can be attached to the spindle at E, so as to be turned round with it; the screw draws the chuck hard up against the end of the mandril, which being turned true, and the shoulder of the screw upon the chuck being also turned true, the chuck fixes so tight to the spindle that it becomes like one piece with it.

it. Some chucks are only flat round boards, and the work is cemented or screwed against them; but the generality of chucks are cylindrical blocks, with a hole turned in the end like a box, into which the piece of wood to be turned is driven fast, so as to be carried about with it. The chucks are generally hooped with iron to prevent their splitting.

The manner of turning in Wood.—To explain all these things in a clear manner, it will be best to describe the simple process of turning a plain cylinder or roller. A piece of wood being chosen, is by means of the saw, axe, and chisel, reduced to a cylindrical form, and by the rasp or draw knife it is made tolerably correct; a chuck is then selected which has a hole in it nearly the size of the piece of wood. The diameter of this being taken in the outside end of the callipers, the chuck is screwed into the mandril, the rest fixed in a convenient position, and the hole in the chuck turned out by the right side tool, *Fig.* 18, to the size measured by the inside end of the callipers. The hole should be rather conical, and the wood being rasped to the same figure, is driven in fast by a hammer. By turning the mandril slowly round, it will be seen if the wood is fixed straight in a line with it, and if not a blow or two of the hammer properly directed will rectify it. The rest is set with its edge parallel to the outside of the piece of wood, and it is roughly turned by the gouge to a cylinder. To do this the gouge is held very firmly down upon the rest, taking its handle in the right hand and placing the fingers of the left in the hollow part near the work; the edge is presented to the work in such a direction that the tool is nearly a tangent to the surface of the cylinder. In this state it cuts best, and must be held very firmly to prevent the edge being depressed by the motion of the work; for if it does, it will take hold too deep and tear the work. This tool is applied first to one end of the work and gradually advanced to the other, turning the work true all the way, and reducing it till the callipers determine it to be near the intended diameter. The chisel is now employed to smooth the cylinder; its handle is held in the right hand, whilst the left grasps the blade and keeps it steady upon the rest, holding the edge a little inclined over the work, so that one side of the flat part of the blade lays on the rest, and the other side is elevated that the plane of the blade, and consequently the edge is not horizontal but inclined thereto; so that one corner of the edge of the chisel is elevated upon the work, then the bottom or near the bottom of the edge of the chisel cuts away a shaving off the work, and this is the only way in which it will cut: for if the edge of the chisel is held parallel to the axis of the cylinder, it acts across the length of the grain of the wood, scraping away the fibres one by one without cutting, and leaves the surface very rough. Some chisels, *Fig.* 16, have their edges inclined for the convenience of holding them properly before the work. The work, being thus reduced to a rough cylinder, must have its end made exactly flat; to do this the thin side of the chisel is laid upon the rest, so that the plane of the edge may stand exactly upright; the hand is depressed that the lower corner of the edge will rise against the work and cut a deep circle into it near the end, and being steadily advanced cuts to the centre, separating a thin round chip and leaving the end quite flat. The cutting corner of the chisel must be directed exactly perpendicular to the length of the work in advancing it, otherwise the end will be either concave or convex, and care must be taken to keep the plane of the edge truly upright and hold it very fine, for there is danger of the work drawing the chisel into the end of it with a deep spiral cut like a screw, and tearing it out of the chuck.

The gouge and chisel are only used for turning soft wood, such as alder, sallow, beech, &c.; but if the material to be turned be hard wood, as *ebony, lignum vitæ*, or *ivory, bone*, &c. the same mode of chucking is employed, but the tools and the manner of holding them is different. The hard wood tools are made with a stronger and more obtuse edge, for a fine keen edge would be carried away by the work when hard. In turning soft wood, as before mentioned, the edge of the chisel is at a considerable distance from the rest, and inclined upwards at such an angle as will cut off the greatest chip. But in hard wood the rest is raised nearly to a level with the axis, so that the upper flat surface of the tool points to the centre of the work to be turned; it is to be held down as firmly as possible to the rest, and advanced to the work at intervals whenever it ceases to cut, by having removed all the projections of the work without the circle it describes by its revolution.

Thus in turning soft wood, the tool is followed to the work, but in hard, the work, by its revolution, comes against the edge of the tool, tending to depress the point and throw up the handle, for this reason it is necessary to hold it very steady upon the rest. Hard wood when first fixed is wrought with the sharp-pointed grooving tool, *Fig.* 10, cuts small contiguous grooves on the surface till it has broken the grain of the wood, removed all exuberances, and reduced the work nearly to its intended size and figure. Thin tools, like chisels, *Figs.* 21, 13, or 17, but made very thick with an obtuse edge and only bevelled on one side, are used to remove the eminences left between the grooves formed by the first tool; the work is then smoothed by applying the edge of a piece of the blade of a broken knife bevelled away, and the work is followed up with it that its sharp edge may scrape away any roughness left by the tools. To polish it, a piece of seal skin, Dutch reed, or glass paper, is held upon the work as it runs round, and cuts away a fine powder, making the work smooth enough to receive a polish. This is raised by applying a piece of bees' wax till the work is lightly covered with it, then burnishing or polishing it by holding a flat piece of hard wood upon it, and the finish is given by the friction of a coarse woollen rag, lightly smeared with olive oil.

Ivory is turned nearly in the same manner, but is polished

lished with chalk and water, and, afterwards by the friction of a woollen cloth. If it is first touched with an oily rag, and rubbed off with a dry woollen rag, it will have a very fine surface.

The reader will by this have a very good idea of the method of turning wood, both hard and soft; and it is plain, if any mouldings or other ornaments are required upon the work, they may be made by some of the tools contained in the plate. Thus, the rough-edge tools, *Figs.* 7 or 8, may be used to turn hollows on the work, and any convex rims may be performed by the chisels, or the side tool, *Fig.* 11. We shall, to give a farther example, describe the method of turning a small round box with a screw lid, as being best calculated to explain every kind of chuck work, and also the method of cutting male and female screws. A cylinder of wood, the size of the outside of the intended box, being formed by the process we have just described, the rest is set opposite the end of it, the edge perpendicularly to the length; then a sharp-pointed tool, *Fig.* 10, is used to bore such a hollow in the end as will form the cavity for the lid of the box, using the outside callipers to determine the size of it. The side tool, *Fig.* 18, is now used to make the bottom of the lid square, or the hook, *Fig.* 9; the edge at the end of the hook being employed to enlarge the inside to the proper size to have the female screw cut within it: to form this, the screw tool, *Fig.* 15, is used; this, as the figure shews, has several teeth, which being applied to the inside of the cylindrical part of the lid, whilst the length of the tool is in the direction of the mandril, will evidently cut as many parallel and equidistant circles as there are teeth in the tool. Now, if instead of holding the tool still withinside, it is first applied at the end of the inside of the lid, and is regularly advanced up towards the mandril, as the work turns round its teeth, it will, instead of describing circles, trace the spirals of a screw on the inside of the lid; and if the advancement is timed so exactly that, in one revolution, the tool is advanced, the exact quantity of a space between two adjacent teeth, then the second tooth will, at the end of a revolution, fall into the spiral cut by the first tooth; and one complete spiral being thus cut, it guides the whole tool by means of the second tooth regularly along, the first tooth continuing the spiral forwards till a third tooth lays hold, then a fourth, and so on, till the required length, or rather depth, of screw is cut: the trace of a screw being thus made, the tool is pressed deeper till the threads are fully formed, the turner taking care every time that the end tooth of the tool gets to the bottom of the lid to disengage it, and draw it back, for, as it could not advance any farther, it would then spoil all the threads by cutting them to circular rings.

This method of cutting screws is called *cutting flying*; and requires great habit and dexterity to give the motion so exact that it will cause the teeth to fall properly into the spirals cut by their predecessors, and this without any sudden advance at the place, for the screw would then be what is called *drunken*, that is, its thread would be more inclined at one part of its revolution than another, and such a screw can never be fitted exactly with its fellow.

The habit of cutting screws accurately with the screw tool can only be acquired by practice and experience; the only precaution which is taken being to get the lathe-wheel into a regular and steady movement, and then to advance the tool with a regular motion, and at such a rate as has been found by experience will be proper for the size of thread intended to be cut.

Professed turners, who are constantly in the habit of cutting such threads, will do them extremely well, but others are glad to avail themselves of the assistance of a regulator, on the mandril; this is shewn at *a*, *Fig.* 1. It is a steel thread, cut very accurately. A small puppet *j* is wedged in the bed beneath this, and in the top of it is a mortise to receive a square piece of wood, which slides in the mortise, by driving in a wedge *d*; the top of this slider has a half-circle cavity cut in it, which embraces the screw, and has a thread in it. The mandril, when this regulator is employed, is made with cylindrical collars at each end, instead of the point of the screw at *c*, so that it is at liberty to slide endways by the movement of the screw, when the wedge *d* is driven in. Therefore, every thing being prepared for cutting the screw, the wedge is driven in; this raises the slider or die up to touch the regulator, the tool is then applied, and the lathe put in motion; the mandril will then move along endways, and also the work with it, so that the tool will cut a screw, although it is held *fast* upon the rest. In this case, the screw may be cut by a single pointed tool, but it will be better to use a screw tool, *Fig.* 15, which is of exactly the same thread as the regulator. The turner should be provided with a variety of sets of screw-tools, and as many regulators, *a*, corresponding to them, which are made like a tube, and fitted on the mandril.

We will suppose, that, by either of these means, the lid, with a screw withinside of it, is finished, and is only to be separated from the end of the wood out of which it is formed; this is done by the parting tool, *Fig.* 20, with which a narrow groove is turned to the centre, and the lid falls off. The box is now began from the remainder of the piece of wood; the first thing is to turn down a smaller cylinder at the end, leaving a shoulder to screw the lid up to: this part is to have the male screw cut upon it. The proper size of the cylinder is measured by the callipers, but it is left rather larger than the screw is intended to be, because it can be reduced gradually by the screw-tool till it exactly fits the female screw in the lid. The male screw is cut by the tool, *Fig.* 14, the rest being shifted parallel to the work; the points of the tool are applied to the cylinder in a line pointing to the centre, and, as the work turns, the tool must have a regular advance given to it from right to left, to trace the spiral for the male screw, in the same manner as the female screw, and this is repeated by returning the tool to the right hand, and cutting again till it comes up to the shoulder; in this manner the screw is

is soon cut up to a sharp thread, and the size of it is fitted to the female screw cut in the lid. Then the length of the screw is adapted to bring the lid true up to the shoulder of the box, so that it makes a perfect joint; in this state the lid becomes again fixed in the lathe, and the top or end of it is turned clean and true. The outside cylinder of the box, and the lid, are turned to the same size, and polished as before directed; this being done, the lid is unscrewed and taken off, the rest turned across the end of the work, and proper tools used to bore or turn out the hollow or inside of the box, and, if the work is particular, the gauge, *Fig.* 25, is used to determine the depth to which it is to be turned. The box is now finished, and only requires to be cut off the end of the wood, by turning a groove with a parting tool till it is separated. If it is afterwards thought proper to turn the bottom of the box flat and smooth, it is done by turning the lid for a second box, from the end of the same wood, if enough remains; then the box, by being screwed into this lid, becomes fixed in the lathe, and may be finished and polished; or, if the turner does not intend to turn any more boxes, he puts a small chuck in the lathe, the outside of which is turned to fit the inside of the box, and this being driven upon it is turned clean and flat at the bottom.

It is unnecessary to give any further example of wood turning in a chuck, but if the work is long and slender, and does not require to be hollow, its extremity is supported by the back centre-point *f*, the other end is driven into a chuck, by which means motion is given to it; or, for some things in soft wood, a chuck is used, which is flat at the end, and has two points fixed in it at equal distances, on opposite sides of the centre; the end of the work being placed against these points, is pressed by the back screw, so that they penetrate it, and it is thus carried about: the turning is conducted just as before described for chuck-work.

This lathe is such as is commonly employed by wood turners, for whose use it is well adapted; but, for turning metal, an iron lathe is best; these are sometimes constructed in the same form as the wooden ones, only differing the size of the parts, which are of cast iron; but this form is unwieldly when applied to delicate and accurate work, such as is required by mechanics, clockmakers, &c.; for their use the triangle-bar lathe is admirably adapted, as it is, also, for gentlemen, who make this interesting art, an amusement, being the most accurate and convenient of any kind of lathe.

The triangle-bar Lathe, on the best construction, is shewn in *Plate* II, with many beautiful tools applied to it, which render it an universal machine, applicable to a great variety of purposes. *Fig.* 1 is an elevation, and *Fig.* 2 is an end view of that part which is above the bench or frame (A, *Fig.* 1, *Plate* I) containing the foot-wheel, which is omitted in *Plate* II, to give the parts on a larger scale. AA, *Plate* II, represents the upper surface of a very thick and solid mahogany bench, upon which the whole is fixed, and the foot-wheel is situated beneath it, if convenient, to apply it in this manner; the puppets, and other parts of the lathe, are all fitted upon a strong triangular bar G, made of cast iron, planed and ground perfectly straight and true; it is supported by standard *a b* and *c*, fixed to the bench by screws, as shewn in the figure. Upon this bar the puppets H, I, and K, are fitted with the most perfect accuracy, and H, which is called the back puppet, can be fastened upon any part of the bar, by a screw *e* beneath it; the other two puppets are likewise furnished with screws beneath, to fasten the bar to them; but these two are supported independently of the bar, being connected together by a thick plate of metal D, screwed to their lower surfaces, and this is fixed on the standards *a* and *b*, so as to form an insulated frame, *a* K, *b* I and D, containing the mandril, or spindle, L. The puppet K, has a steel pivot with a hole in the end to receive the pointed end of the mandril L, a screw *f* is placed behind to force it up, and another at the top, to fasten it when adjusted, so that the neck of the mandril will exactly fit, without shake, into the steel collar which is fixed in the upper end of the puppet I. The back puppet H has a hole bored through it, exactly in the line of the spindle, to receive a cylindrical steel pin *n*, which has a sharp conical point to support the end of a long piece of work: a screw *m* is placed behind to force it up and keep the work always tight, and a screw *z* fastens the pin in its place.

The rest of the lathe is thus made:—A brass piece *o o*, called the saddle, is fitted upon the sides of the bar; upon this a steel slider *p* is fixed, having a tube Y to receive the shank of the rest T, with a screw to fasten it at any height; the slider *p* has a dove-tailed groove in its lower surface (see *Fig.* 1), for the reception of dove-tails, formed, at the upper ends, of two steel bars, shewn by the dotted lines 1, 2, in *Fig.* 3; the two bars are united by a horizontal piece beneath the bar, the whole being made of one piece, bent like a staple or fork, and its two arms, 1 and 2, fitted in mortises cut through the saddle; by this means, a single screw, 4, tapped through the horizontal piece, and the point pressing on the under side of the bar, will fasten the rest, drawing the slider *p* down upon the saddle, by the two dove-tails, and, at the same time, drawing the saddle down fast upon the bar.

The mandril L is made hollow nearly through, and, at the open end, is cut with a female screw, for the reception of male screws upon the various chucks, which fit to the lathe. This is a better method than the common way of a male screw on the mandril, because of the care with which the male screws for the chucks can be cut in brass, and the convenience of putting long work up the hollow mandril. This lathe has all the parts before described of the wooden lathe, but is far more convenient, because of the ease with which the puppet and rest can be shifted and fixed by only the finger and thumb, and yet the whole is much stronger, the puppets being so low from the bar; and another advantage is, the accuracy with which the back centre-point *n* always keeps in a line with the mandril, which is indispensable for

for good turning; also, the puppets being so slender, the operator has better access to the work than between clumsy wooden puppets, and which are not so strong as the small metal ones.

When very large or very long work is required to be turned in this lathe, another standard exactly similar to *c*, is placed under the bar in the position shewn by the dotted lines, 5, *Fig*. 1; the bar is then drawn out, leaving the mandril standing between the two standards I and K, in which situation it will admit a piece of work of very large diameter. The rest is fixed upon the end of the triangular bar which projects beyond the dotted standard 5; or, if any long work is to be turned, the back puppet H is to be placed on the end of the bar beyond the standard *c*; this, as well as the temporary standard, has a thumb screw in the under side, between its legs, to fasten the bar in it. The most convenient method of fastening the temporary standard upon the bench A, is by means of a piece of brass, 5, screwed fast upon the bench; it is dove-tailed in between the two legs or feet of the standard, and thus holds it fast down, though it can be removed by sliding it endways, without drawing any screw. By this contrivance of drawing out the bar, the lathe has all the conveniences of a small and delicate machine, when used for small work, but the strength and other advantages of a large one when required.

The small figures in the plate describe the chucks and other very useful tools, which are occasionally applied to this lathe.

Fig. 7 is a section of a wood chuck, the uses of which has been fully explained in the description of the wooden lathe. A brass screw, D, is cut to fit the mandril; the other end, E, is also cut with a screw, which is forced very hard into the wood F, so as not to come off without great force; by this means the fitting of the chucks to the mandril is not with a wooden screw, as in general, but with a brass one, which will not be liable to get out of truth, but always screw up to the same shoulder; the lathe should, at least, have two dozen of these wood chucks, some of them hooped, as at *d*, to prevent them splitting.

Fig. 11 is a very useful arbor, for turning wheels, collets, &c., or any other flat work that will admit of having a small hole in the centre of it; it is a brass screw chuck *a*, fitted to the mandril, and a steel pin *d*, shewn by the dotted lines fixed into it, and projecting an inch or more; it is turned true, and the work fitted upon it either by turning the pin to size, or by broaching the hole in the work; and, to prevent slipping, the work, marked E, is jambed fast up against the brass shoulder *b*, of the chuck *a*, by a nut *c*, tapped on the end of the steel pin; by this the work E will be held fast, and be carried round by the chuck, so as to be turned by the application of proper tools upon the rest.

Fig. 10 is a watch-maker's arbor, for similar work to the last, but where the work is thick enough to stand fast in the square without requiring the support of a shoulder, or requiring a nut to screw it fast. A is a chuck made hollow like a box, with a small piece of hard steel *b*, having a small hole through it, exactly in the centre. B is a watch-maker's arbor, such as is used in the turn-bench; it is made of steel, rather conical, but turned extremely true; one of its points is to be supported in the hole in the centre of the chuck, and the other end in the back centre of the lathe. The work to be turned has, as before, a hole in the centre of it, and the arbor is driven into this till it is fixed quite fast upon it; then, to turn this arbor about by the mandril, a piece of brass *c*, called the driver, is tapped upon the arbor, and fixed fast by being screwed up against the pulley *b*, which is fixed on the arbor; the ends of this piece are received in notches made in the opposite sides of the box chuck A, at *d d*; by these means the motion of the lathe is communicated to the arbor to turn the work rapidly till it is near its dimensions; and, having done this, if extreme truth is required, the arbor is to be taken out of the lathe, the driver *c* is unscrewed, and the arbor is turned by the bow in the manner of a turn-bench, which will be described; so that if the hole *b*, in the chuck, should not be exactly in the centre of the mandril, the error will be rectified.

Centre work, such as a long axis, or arbor of steel, may be mounted in the lathe by two methods:—In one, a small chuck, with a square hole in the end of it, is screwed into the mandril, and the work has a square filed at one end to fit this hole, the other end is supported by the back centre, a small hole being made in the end to receive its point; or, if the end of the work is pointed, the back centre is drawn out, and turned end for end, the end opposite to the point having a small centre hole for the reception of such pointed work. This method of turning the work, by means of a square, is very convenient but not very accurate, and if the work should, at any future period, be required to be returned in the lathe, its true centre cannot be found again; therefore, all spindles, arbors, axles, screws, &c., are turned between centres: thus, a chuck H, *Fig*. 12, is screwed into the mandril, it has a steel centre-point formed at the end of it, which is turned extremely true, to be in the centre of the mandril; between this and the point of the back centre, the work is mounted, and, to give it motion, the driver, *Fig*. 5 or 6, before described, is screwed on that end of the work nearest to the chuck, which has a steel clutch D fitted into it, and fastened by a screw; the end of this is bent so as to clutch the tail of the driver W, and thus turn it round, and the work all together; the clutch slides in and out to adapt itself to different sized drivers for delicate or large work. This method of turning is best, because the centres are preserved, and, when one end is finished, the driver may be shifted to the other end; or such work may, at any time, be mounted again in any kind of lathe, to turn wheels, collets, &c., which may be fitted upon it.

In *Fig*. 9, are two views of a very useful chuck to hold brass or steel wire, for turning screws or small pins. It is a steel or brass tube A B, with a screw B to

to fit the mandril, and it has also six small screws; three at $a\ a$, and three at $b\ b$, pointing to the centre, as shewn in the end view. The points of these are screwed fast to pinch the wire between the points. By this, a long piece of wire, of any size, may be held, the greatest part of its length being put within the hollow of the mandril, and only as much left projecting beyond the chuck as is sufficient to turn one or two screws, which being finished, by slacking one of the screws another length of the wire may be drawn out. The three screws give the means of centering the wire very truly, so as to waste very little.

Fig. 12 is an apparatus useful for many purposes when the small centre hole at the end of any long piece of work has been lost, or cut away, and it is necessary to put it in the lathe again. H is a horizontal section of the back puppet; through the middle of its centre-pin *n*, the cock of the screw *m*, *Fig.* 1, being removed. A B C is a piece of steel screwed to the face of the puppet H, by screws B and C, which being fitted in grooves, permit the steel to slide; it has a conical hole through it at A, exactly in the line of the centre-pin, and in this the end of any piece of work may be supported, if the centre is lost. The same apparatus is also useful to drill small tubes of brass from a piece of wire, as F, *Fig.* 12; this is shewn with a driver W of the same form as *Fig.* 5, screwed on one end of it, which is supported by the steel centre-point of the chuck H, screwed into the end of the mandril. The wire is turned round by the steep arm D attached to the chuck, and intercepting the tail of the driver W; the other end of the wire is supported in the conical hole at A. The drill is applied thus; a cylindrical pin of brass K is drilled through with a small hole of a proper size to receive a metal steel wire L, the point of which is made to a drill; the outside of the pin K is turned to fit exactly in the hole through the back puppet H, then the drill L, being thrust forward by hand, will be exactly in the centre of the work F, which is to be bored, and may be occasionally withdrawn to clear the chips, which would otherwise clog it up, and break a small drill. By this apparatus, tubes, not larger than a pin, may be drilled up four or five inches, and perfectly straight.

Fig. 8, is a stock for drills, consisting of a steel arbor, *v*, with a square hole in the end of it, fixed fast into a brass screw A, which fits it to the mandril; then a drill *b*, being fitted into the square hole at the end of it, forms a very complete drilling machine; the work to be perforated is held against a flat chuck B, which is pushed upon the centre *n* of the puppet H, and the screw *m*, advances it to the drill: the great advantage of this method is that it will always bore perpendicularly to the flat sides of the work.

An apparatus is fitted to this lathe for turning cylinders, or cutting screws, in the following manner: two strong steel rods, 7 7, *Figs.* 1 and 2, are fixed fast into the saddle *o o* of the rest; these rods must be exactly parallel to the bar, and are received in holes through a piece of brass, 8, fitted upon the angle of the bar; it has two screws to fasten it to the rods at any distance from the rest, and then it gives the rest two bearings on the bar, at a considerable distance asunder, viz. from *o o* to 8, *Fig.* 1; a heavy weight of cast iron is suspended under the lathe from the two rods, 7, and thus keeps the whole tight down upon the bar, whilst it slides in the most accurate manner from one end of the lathe to the other, and exactly parallel to the axis of it, the screw 4 under the saddle of the vest is of course turned back to admit of the motion; but as it is necessary to fix the steel slider *p*, firmly down upon the saddle, it is done thus; two bars of steel are fixed across the underside of the brass saddle at 10, 10, *Fig.* 1, so as to have one on each side of the bar of steel fork, 1, 2, *Fig.* 2, before described; then a washer, being put under the shoulder of the screw, 4, and resting upon the bars, 10, 10, the point of the screw will not touch the bar when screwed tight, but will draw down the fork 1 2 3, thus fastening the slider, *p*, upon the saddle, but leaving the saddle at liberty to slide along the bar freely; the washer being removed, the screw, 4, will fasten the whole rest upon the bar as before described.

The tool, for cutting screws or cylinders is fixed in a small apparatus called a slide rest, shewn in *Fig.* 2; it consists of a strong plate, 12, with a stem or shank, to fix into the tube, *y*, of the rest, and upon this a dove-tailed piece is fixed by two pieces screwed down upon the plate, 12, at each side of it, to form a dove-tailed groove; at the ends of the slider two cocks or holders, 14, rise up from it, which have holes for the reception of the tool, 15, and screws to fasten it in a screw turned by means of a key with a milled head applied to its square, shewn near 12, is employed to force the slider and tool forward to its work. In this state the lathe is prepared for turning an exact cylinder mounted between the centres of the lathe, the tool being fixed in its holders, 14, and its point set to the proper depth by the screw 12, it will be held fast without the aid of hands, and the whole slider being traversed along the bar, the tool advances in a right line parallel to the axis, turning the cylinder exactly true and of any required diameter, according to the depth to which the tool is set by the screw 12, with the greatest ease, which is a great convenience for many kinds of work, as it turns much more accurately than can be done by hand; but when it is required to advance the tool with such a regular progressive motion as will trace or cut out the spiral of a screw upon the circumference of the cylinder, the following additions are made: a cock, *t*, *Fig.* 1, is screwed on the side of the puppet I, it has a socket formed in it for the reception of the end of a long screw, shewn by the dotted lines *t*; it is tapped through the saddle *o o* of the rest, at *t*, *Fig.* 2, so that by turning this screw the rest is caused to traverse along the bar of the lathe; the motion is given to the screw by a cog-wheel, 17, fixed upon it, and the chuck of the lathe has also a wheel, 18, *Fig.* 2, fixed upon it, the motion being conveyed from one to the other by means of an intermediate

diate wheel shewn by the dotted circle in *Fig*. 3, which turns on a pin fixed in a piece of brass, held by a screw against the face puppet I, so that it can be adjusted into a proper position, to gear or work, with both wheels, 17 and 18, let their relative diameters, be what they may. The proportions of these determine the size of the screw, which will be cut upon the cylinder in the lathe, for the thread of the screw which is cut will bear the same proportion to the thread of the screw *t*, as the two wheels 17 and 18 bear to each other. Thus if the screw *t*, has twenty threads per inch, and the wheels 17 and 18 are as 2 to 1, the screw which is cut will have forty threads per inch. For cutting female screws, the same method is used, but a tool formed like a hook is used that its point may enter a piece of hollow work when it is put in the chuck at the end of the mandril.

This method of cutting screws by the lathe is preferable to any other, as it admits of the greatest accuracy, and is quite general, for if the regulator screw *t*, is perfect and correct, it will cut a correct screw of any kind, and, by having a number of wheels, any kind of screw may be cut, and any form of thread, either sharp or square; the tool used for it may be either a single point, or a screw tool such as before described, which will cut best, because it guides itself, and, therefore, does not throw so much strain upon the regulator screw *t*, by means of the sliding rest has been explained; it is one of the greatest modern improvements in the art of turning metal to employ the slide rest, for all kinds of work, which it will do with the greatest dispatch and accuracy, and without any labour on the part of the workman.

A complete sliding rest is shewn in *Figs*. 3 and 4, fitted to the triangle bar lathe, the first of these figures, is in part a repetition of the mandril as shewn in *Fig*. 1, and its frame, to shew the manner in which the slide rest, applies itself to the work held in a chuck, at the end of the mandril, the slide rest has two horizontal sliders in directions perpendicular to each other, to one of these the tool is firmly attached, and by means of screws with handles, the sliders and the tool can be moved in any direction to follow the tool to the work; 12 in both figures is a frame of metal, fitted to the bar of the lathe, and provided with a screw beneath to fasten it at any place; upon its upper surface, which is made flat, two pieces of brass are screwed, to form a dove-tail groove, in which a steel slider, 13, is fitted to move with freedom and precision; a screw is mounted in a frame, and is tapped into a piece of metal, projecting from the lower side of the slider, so that the screw, when turned round by a handle, 15, fitted on its square end, advances or draws back the slider in its groove. Upon this slider, a frame, 16, is screwed, having a second slider fitted on the top of it, and provided with a screw, 17, as the former to move it, and this upper slider carries a piece of metal, 18, with square holes through it in two opposite directions to receive the tool, and a screw at top to fasten it in. The slide-rest being mounted in the manner of *Figs*. 3 and 4, upon the bar; the upper slider is parallel with the mandril, and the lower one perpendicular thereto. For turning flat work, the tool is put in as there shown: Now, by turning the screw, 17, of the upper slider, the tool is advanced in contact with the work, which is mounted as in *Fig*. 3; then, by the other screw, 15, it is drawn across the face of the work, turning it, as it proceeds, to a perfectly flat surface. For turning a cylinder, mounted between centres, the tool is put through its holder, in a direction perpendicular to that shewn in *Fig*. 3, and then the screw, 15, of the lower slider is moved to adjust the tool to the diameter of the intended work, and the upper slider is moved by its handle, 17, to carry the tool along the length of the cylinder, and cut it as it goes: the whole rest can be fixed at any part of the bar, and can be removed instantly if required. The slider rest will also turn cones, by the following contrivance:—The frame, 16, supporting the upper slider, is fitted to the lower slider by one pin, upon which the whole frame and the upper slider may be turned round, and fastened at any inclination by two screws *r* passing through circular grooves. By this means, the upper slider is inclined in any required angle to the mandril, and will then turn a cone, either hollow or solid, according as the tool is put in its holder, 18, in one or other direction. The great advantage of the slide rest is, that it presents the tool so firmly to the work that it will not retreat in the least when any protuberance comes by, but cuts it away if the strain is not so great as to break the tool, but of this there is no danger if it is properly managed, because the screw advances the tool so slowly that there is no need to push it forwards suddenly, as it is often unavoidable in turning by hand. The sliders are often divided into inches and subdivisions, by which the work can be made exactly to any dimensions, without trouble; any two things may be fitted exactly together; and the upper slider has an index to shew the angle of inclination which it makes with the lower, when set for turning cones, so that a hollow cone being bored out in a chuck, a solid plug may be turned to fit it, the rest, without trial, making it certainly of the true angle. A very convenient universal chuck is shewn in the act of holding the piece of work, in *Figs*. 3 and 4; it consists of a flat circular plate D, having two grooves in it pointing to its centre: these grooves contain sliders, which have steel jaws *a*, similar to those of a vice, attached to them, for the purpose of clamping the work between their teeth. The sliders go through the plate at *b b*, *Fig*. 3, and have a screw *c*, tapped through them; one end of this screw is cut with a *right-hand* thread, and the opposite end has a *left-hand* thread; so that the inclination of the spirals, upon the two ends, are contrary to each other; by this means, when the screw is turned one way round, by means of a key applied to its end, it will cause the two sliders to recede mutually from the centre of the chuck; but, on turning it in the opposite direction, they will advance towards each other, always keeping

keeping equally distant from the centre, by which means any piece of circular work, F, may be held on the lathe to be turned, with the same ease and steadiness as it would be fixed in the vice to be filed; the circular plate is screwed against a centre piece, G, which is screwed into the mandril, and is cut hollow to permit the sliders to come almost close to each other when small work is to be held between them; the centre piece has also a collar for the reception of a neck formed in the middle of the screw between the two threads, to prevent it moving endways, or the work would be at liberty to slide backward and forward in the grooves of the flat plate, but this collar makes it all fast.

Metal-turning tools.—The tools used for turning brass or cast iron, are made from bars of steel; for as those who turn metal are usually general mechanics, they make the tools themselves, and adapted for any particular occasion they require; the principal tools are *gravers, square tools, pointed tools, round tools,* and *hooks.* The graver, see *Fig.* 6, *Pl.* I, is made like those used by engravers, from a square steel bar, cut off by an oblique plane at the end, which makes a lozenge, or diamond face, and produces two inclined edges at two of the flat sides of the bar; these two are inclined opposite ways, so that the graver serves either for left or right-hand work by only turning it one quarter round to bring up another side. The point formed by the acute angle in which the two inclined edges meet, is best adapted for cutting of any other form, and is exceedingly strong; the flat sides give it an excellent bearing upon the rest; another convenience of the graver is, the ease with which it is sharpened, which is an object in turning hard metal, when it is so frequently necessary; it only requires to be held on the grind-stone in the proper angle, to grind the diamond face away, and thus make sharp edges with the two flat sides. Gravers, and all tools for metal, are hardened and tempered to a light straw colour, so as to leave them very hard; cast steel is the best material. The graver is used to rough the work, its point being used to cut grooves all over the surface till it is true, and then the welved edge of the graver, or else a square or round tool, makes it smooth and a proper figure. It is necessary in beginning to turn with a small sharp point, for the resistance to any kind of edge, would, in beginning, be so great as to tear every thing in pieces. Square tools are made like a narrow chisel, except that they are very thick, and the angle of the edge very obtuse; the upper surface which is flat, is, in turning, made to point to the centre of the work. Round tools are like the former, except that the edges are made round for forming hollow mouldings, &c.

The pointed tool has two inclined edges forming a point which cut grooves in any piece of work; or its edges may be used to turn shoulders either right or left.

Drills of various sizes to bore holes in chuck work; they are fixed in handles.

Right and left side tools, such as before described.

Heel tools are used for turning wrought iron, steel or copper; they are made with edges of all the shapes above-mentioned, but the end where the edge is formed is bent, so that when it is presented to the work in its proper direction, the handle is inclined upwards, in such a position, that the end of it will lay on the turner's shoulder, and he holds it down firm with both his hands, the heel of the tool being supported on the rest. The metals above-mentioned are of a fibrous texture, and turn away in a connected shaving, the tools are therefore presented in the direction of a tangent to the work, the same as for soft wood; but as the drift of the work would force the tool endways, if held in the same manner as the chisel, it is necessary to have a heel, or angle, which is placed immediately upon the rest, then the long handle serves to guide and fix it, and by elevating the end the edge cuts deeper.

Cast iron is turned by hook tools; their edges are formed in various ways, but very obtuse, being nearly a right angle: in turning they are held in such a position, that a line bisecting the angle of the edge is made to point nearly to the centre; but as the work is usually large, and the metal very hard, some contrivance is requisite to keep the tool up to the work, they are therefore made with a hook which has the edge at the end of it; the hook part is laid over the rest, in the same manner as a crow bar is used to draw out a spike or nail, and then by raising or depressing the end of the handle, the edge is caused to approach or recede from the work with any required force, by only a moderate power applied at the end of the long handle; cannons, and other heavy cast-iron work, are turned in this manner.

The chucks used for turning metal are different from those used for wood, because the articles are so various in shape, and projecting pieces are never made for the purpose of holding the work, as can be done in wood; small brass work is held in wood chucks; brass wheels, collets, rings, &c. are chucked on the arbors, *Fig.* 10, or 11, but if they are large, and require to have the centre hole bored or turned out, they are fastened against a flat chuck, by screws or small bolts with nuts at the back; this method is very general for all kinds of flat work, and the lathe should have two or three sizes of flat circular chucks, turned perfectly true, and drilled with a great number of holes for the reception of screws in any part, by which the work may be fixed against it.

The universal chuck before mentioned at *Fig.* 3, will hold almost any kind of work, and will supersede the necessity of most others. Some turners use instead of it a circular box with three or four holes tapped through the sides of it and pointing to the centre; this is convenient for some work, because it admits of adjusting the work truly to the centre. The steel for the dies used for coning are checked in this way.

The only difference in the management of turning different substances is, to adapt the velocity of the motion

motion to the nature of the material; thus wood will work best with the greatest velocity which can be given to it, and of course a thin and delicate shaving must be cut off; brass should have a motion about half as quick as wood; iron and steel should be considerably less, though few mechanics attend to this: cast-iron must go very slow, and the chip which is taken off will be in proportion, in order to save time. If these circumstances are not attended to, the edges of the tools will be destroyed; for it is a curious fact, that a soft substance will wear away or cut the hardest steel by only giving it a sufficient velocity, most probably by heating or softening the steel just at the edge; this will be avoided by properly adjusting the velocity; for this purpose, the pulley or mandril is made with a number of different sized grooves for the band, and the foot wheel has likewise three or four grooves of different sizes corresponding with them, so that by shifting the band from one to another, any required velocity may be given. A complete lathe should have a pulley on the axis of the foot-wheel, not much larger than that on the mandril, for turning steel or cast-iron, though this material, being generally used for very large work, is not often turned in a foot-lathe. For these purposes a large massive lathe is employed; it is generally made in cast-iron, in the same form as the lathe in *Plate* II, but turned by a steam-engine or horse-mill; the endless strap which communicates the motion being worked upon a live and dead pulley fitted on the mandril, for the convenience of discontinuing the motion at pleasure. Mr. Maudslay, of Westminster road, Lambeth, who has a more complete and extensive turning-shop than any other mechanic, employs the triangle bar lathe for the largest work, the bar drawing out to admit it, and all his lathes are provided with slide rests and universal chucks, like *Fig.* 3, which instrument he first introduced into general practice; his lathes are made in a more elegant form than that represented in our Plate, but contains all the same parts and has the same uses.

The reciprocating motion of a treadle and string, like the centre lathe, is never used for turning large work in metal; as the time and labour employed to do it in this manner would be too great to answer; but artists who make small work, as watch and clock-makers, are constantly in the habit of using.

The Turn Bench.—This is a small centre lathe in which the motion is given to the work by means of a bow, like that used for drilling. The *turn bench, Fig.* 14, *Plate* II, is a very convenient kind of lathe for small centre work, for it requires no frame, but is held in the vice; A A is the bar, made of iron, very straight and true at one end, the puppet B is fastened perpendicularly to the bar; it has a hole drilled through it at top to receive a cylindric steel pin, *a*, which is the centre point, and a finger screw, *b*, to fasten it; D is a puppet similar to B, but moveable along the bar to any place to suit the length of the work, where it may be fixed by the screw *d*; E is a socket for the rest, sliding on the bar, and furnished with a screw, *e*; it has a hole through it perpendicular to the bar, to contain the slider *f*, *Fig.* 15, of the rest; this slider when in its place, touches the top of the bar A, that when the socket E is drawn by its screw *e*, the slider *f* is held tight from moving either in a direction perpendicular or parallel to the bar: F is the rest, supported by the slider *f*, and fixed at any height from the bar by the screw *g*; the steel centre points, *a a*, have a sharp conical point at one end, and in the other a fine hole, and either end is used according to the nature of the work.

The manner of using the turn bench will be best understood, by describing the method of making a small ring or collet of brass; a piece of brass plate is first to be selected, of the proper thickness, and the hole drilled and opened out by a broach to the intended size, then with a pair of conical-pointed compasses a circle is drawn round the hole, a small quantity larger than the ring to be made, and by the saw, cold chisel, or shears, the brass is cut out to the circle, and smoothed on the edge by the file; in this state the ring is to be driven tight upon an arbor, G, see also *Fig.* 10; it is a conical steel wire, with sharp points at the ends turned truly; several sized arbors of this kind accompany a turn bench for various sized works: the string, or rather catgut of a drill-bow, is now to be passed round the small brass pulley H, fastened on the arbor, and the arbor and collet are to be placed in the turn bench by first sliding the puppet D on the bar to the proper distance to receive the arbor, and fastening it by the screw *d*, then inserting the point of the arbor into the hole in the end of one of the pins *a*, and pushing the other up till the arbor has no shake, the screw *b* being turned will prevent it getting loose; the rest F must now be fixed opposite to the work and close to it, by the screw *e*, and set rather below the level of the centre of the arbor; the whole turn bench being screwed in the vice by the part *n*, the turning is began by drawing the bow held in the left hand backwards and forwards; this causes the work to turn round, and a graver, or other turning tool before described, being held in the right hand over the rest to the work, soon cuts it to a circular figure. In the same manner, by means of various sized arbors, small globes, nuts, or any other work which will admit of having a hole through it, may be formed in the turn bench.

A different method is employed in turning pins with heads, small spindles, or arbors for wheels, &c.; these are made from brass, or steel wire, and the workman must provide himself with a number of small brass pulleys, each having a small hole through it, which holes are of different sizes, to suit various work; if a piece of steel wire is to be turned, it must be filed to points at the ends, and one of the ends made a little conical, then by driving it into one of the brass pulleys it may be turned by the bow, in the same manner as the collet above described. But for some peculiarly nice work, as the arbors of watch wheels, &c. which are

are cylindrical, and therefore will not receive a brass pulley without danger of slipping, another kind of pulley must be used; a simple one for this purpose is made of wood, and has a conical hole through it; this being driven on the cylindric wire or arbor, will accommodate itself to the size of it without bruising or disfiguring the work, as the brass pulley would if it should slip about it. The small pulley or ferrule shewn at *Fig.* 13, *Plate* CLOCK-WORK, is intended for this kind of work; it is a steel ring or pulley, having a small bar left across it, this bar is tapped to receive two screws, by which another moveable bar is drawn up towards the fixed one; a small notch is filed in the middle of each bar to hold the work, and by the screws it will adapt itself to work of different sizes; as the fixed bar is in the same piece with the pulley, it will only fit one size of work to be concentric with the axis of it; but this is not material when the pulley is to be turned by a drill bow, for the string passes all round it, and will not be more liable to slip for the pulley being eccentric. A brass pulley, made like *Fig.* 13, is intended to be fitted upon work which requires that it should be concentric, and is adjusted by means of its three or four screws, *a a*, as described before for the centre lathe. When pins are to be turned from brass wire, the sharp points at the ends of the pivots *a a* of the turn bench are to be used, and corresponding holes made in the ends of the brass wire; for if points were made to the ends of the brass, there would be danger that they would be worn away before the work was finished, and it is not an easy matter to find the centre again; the treatment is the same in other respects as for steel, except that different tools are used for cutting it.

In turning either brass or steel wire, it sometimes happens that the wire is small, and is not of sufficient strength to bear turning, or it may be in short pieces, in such cases a stock is employed; it is an arbor made of steel, with a brass pulley fixed on at one end, the other end is perforated with a round or square hole to receive the end of the short piece of wire which is to be turned; this wire is to be pointed if steel, or if brass, it should have a small hole in it for the point of the turn bench centres, *a a*, between which it is turned as before-mentioned; a notch is filed in the stock near its hollow end, so as to expose the end of wire which is driven into it for the purpose of introducing the end of a screw driver, or any other similar tool to force out the wire, for after it is turned it cannot be drawn out by the pliers or vice without injuring, or perhaps destroying the work: for turning very small work, a round hole in the end of the stock will answer very well, without slipping, but the larger articles must be turned in a stock which has a square hole, and the wire is filed square to go into it. Another very useful appendage to the turn bench is, a pin or pivot, see K, *Fig.* 11, *Pl.* CLOCK-WORK, which is fixed in the place of the centre points, *a* or *a*, for the purpose of turning exceedingly fine pivots to the arbors of wheels, or for making sharp points to pins; it has a conical hole drilled up it, opening into a notch *d*, filed in the point; the article to be turned is prepared for this point by first turning it by the common centres until the end of the work is small enough to go through the hole in the point, and project into the notch *d*; in this state, the bearing for the turn is taken on a shoulder which rests against the end of the point, and the end of the pivot, which is beyond the hole, is relieved from the strain occasioned by the motion of the bow; and may, in this state, be wrought extremely fine by files, and, afterwards, by emery, or powder of rotten stone, spread on the end of a piece of steel, and held against it.—*See* WATCH-WORK.

Turn benches are greatly used by watch-finishers; indeed, many have no other lathe or turning machine than a turn bench and a turn. Their turn benches are often made and finished in a most capital manner. The best sort are called Geneva turn benches, and are like *Fig.* 14 in shape; they are made of iron, and case-hardened, so that a file will not touch them. The points *a a*, are made to fit their sockets very truly, and to defend them from receiving injury from the end of the screw *b b*, pieces of steel, called *bridle-bits*, or, more properly, *saddles*, are placed upon them. A square hole is made through the puppet, intersecting both the hole for the screw *b*, and the hole for the point *a*, at right angles. The saddle is a small piece of brass inserted into this hole, covering the centre-point, and preventing the end of the screw from touching it, at the same time giving the screw a firmer hold of the point, and preserving both point and screw from injuring each other. The saddle is prevented from dropping out of its hole, when the screw is loose, by a screw which passes through a square piece of plate which is in the same piece with the saddle; in the same manner, a steel spring is interposed between the end of the screw *d*, and the lower side of the bar A A; and these springs act when the screws are slack, to make the puppets slide stiffly, yet smoothly, along the bar A A.

A wheel and a pulley are sometimes applied to a turn bench in the same manner as the centre lathe used by millwrights. It is then called a *throw*, and is used for turning small screws, &c., in brass; in this case, a brass pulley as large as will conveniently turn in the turn bench, is fitted upon one of the centre points *a*; an opening is filed out in the pulley exactly similar to one of the openings which would be in it if it were filed out with four arms, and the remaining solid part is tapped with several holes at different distances from the centre, to receive pins, in the same manner as the centre lathe above described. The pulley is turned by a cat-gut band from a wheel worked with a handle; the wheel is mounted in a frame fixed on a board, and the turn bench is set up in a frame fixed to the same board, before it; the arbors, and other pieces of mechanism, used in the turn bench, are turned by small drivers made like *Fig.* 5, or the ends of them are filed square, and driven

driven into pieces of brass plate, which are pushed round by the pins in the pulley.

The watch-maker's turn, shewn in *Pl.* Clock-work, *Fig.* 11, is the tool in which he turns the most delicate and minute work. It is described in our article Watch-work.

Elliptical Turning.—This is performed in the same lathe and with the same tools as the circular work, but the lathe is provided with a chuck which causes the work to traverse in a very curious manner, to and from the centre as it revolves, so that a tool, held up against it, will cut it into an elliptical figure instead of a circle. The work has a curious appearance, when in motion, for, after the work has been turned truly elliptical, every part of the circumference, except the exact point where the tool is applied, appears to wabble, or be eccentric, in a great degree, but that one point of the circumference runs perfectly true and regular, the same as the whole circumference of circular work does. The mode of action of this ingenious chuck is rather difficult to describe, but we will endeavour to give an idea of it, by adverting to the principle of its action. This is the same as the trammel, or elliptic compasses, see *Fig.* 16; these consist of a circular or square board A A, B B, having two grooves in it perpendicular to each other, this is fixed down upon the surface where the ellipse is to be described; the centre lines of the grooves, forming the two diameters thereof, and, of course, their intersection its centre, so that the curve will be traced beyond the circumference of the board by means of a pen or pencil, which is fixed at C to a radical bar or beam E, the above carries two points or pins F G, which are attached to dove-tailed sliders inserted into the grooves of the board as shewn in the figure; they are fitted in truly, so that each of the dove-tails have a motion in its grooves, G moving along B B, and F along the groove A A. By turning about the beam E, they go backwards and forwards along the cross grooves, so that when the beam has gone half-way about, one of these sliders will have moved the whole length of one of the halves of the cross, and when the beam has gone quite round, the same dove-tail has got back the whole length of the cross. The same applies to the other dove-tail.

The pins F G and C can be fixed at any part of the beam E at pleasure (though not represented so in the figure), for the purpose of setting it to draw any particular ellipses; thus place the beam in the direction of the line B B, then the pin F will be in the centre of the cross grooves; now fix C at such a distance from the centre F as is equal to half the small diameter of the ellipse, and set G so far distant from F as the difference of the two diameters; consequently, from C to G will be equal to half the longest diameter. Now, in turning the beam round from the direction B B till it comes to A A, the point F will depart from the centre along A, and G will approach it along B, till it gets to the centre; then will C be so much farther from the centre as F is distant from G, and has in its circuit traced one-fourth of an ellipse; and, the beam being turned quite round, will complete the whole curve. To shew how this apparatus may be applied to turning, we must suppose the cross groove, made in a round board, as large again as the figure; then, if it is inverted, and the beam E held fast in a vice, or otherwise, the board with the cross may be traversed round upon the dove-tails in the same manner as the beam could be traversed round upon the board: Now, if we suppose a tracing point, fixed exactly opposite the place where the tracing point C is fixed to the beam, it is evident its point will trace the same ellipsis on the back of the board, which was before described on the face of the surface it laid upon; or, a chisel being held fast here, will cut the board elliptical when turned round, and being successively applied at different points along the line of the beam E, a series of concentric ellipses may be turned in the board to make mouldings for picture-frames or other ornaments; the distance of the two fixed pins F and G being altered, will, at pleasure, vary the proportion between the diameter of the ellipses in the same manner as before described.

The oval-chuck is constructed in a different manner from this, though it preserves the same movements. It consists of three parts—the chuck, the slides, and the circle. The chuck H H, *Fig.* 17, is attached to the mandril, by a screw projecting from the centre of it behind, and turning round with it. *Fig.* 18 is a view of the chuck behind, where the screw is marked *k; the chuck* has a dove-tailed groove formed in it at the part for the reception of a slider K, which traverses freely in the groove; this is formed as the figure shews, by pieces *a a* screwed to the chuck on each side. The centre of the slider in front has a screw L, *Fig.* 17, projecting from it, by which a wooden chuck may be screwed against the slider, and any work can be fixed in it in the usual manner, so that the work, at the same time it turns round, by the motion of the chuck, has a sliding motion across the cutter, which being given in a certain line produces an elliptic motion. The sliding motion is given by the circle, *Fig.* 19. This is a ring of brass M attached fast to the puppet of the lathe, the mandril passing through the aperture N: the ring has a flat plate O, to strengthen it, and forming two bends at the ends, which have screws P Q tapped through them, and pointing exactly to each other; these screws have sharp points which enter small holes in each side of the puppet, and the back of the circle M lying flat against the front of the puppet, is, by this means, fixed fast; the two screws P Q being then horizontal, and both pointing to the centre of the mandril; but, by screwing one screw in, and the other out, the whole circle may be brought forwards horizontally so as to give it any required degree of eccentricity from the mandril, and it will be stationary wherever it is placed. *Fig.* 18, which is a back view of the chuck, shews two grooves made through it; then admit the shanks of two straight-edged pieces of steel R R, which are firmly attached to the slider by a screw for each, as shewn at *p p*, *Fig.* 17, in

in front thereof. The two inside edges of R are exactly parallel, and the distance between them is exactly equal to the diameter of the outside of the ring M, which is included between them, when the chuck is screwed to the mandril, and the circle fixed to the puppet, as above-mentioned. Suppose then, the circle M is set concentric with the mandril, which being turned round, causes the chuck and slider together with the work attached to the screw L, to revolve; but the work will now run in a circle, and turn circular work as usual, because the slider is guided by its claws R R, embracing the circle M, to keep the same position in its groove in the chuck, during all the parts of a revolution. Now place the tool at such a distance from the centre that it will describe a circle of equal diameter to the breadth, or smallest diameter of the ellipses intended to be turned (this is best done by fixing the tool in the slide rest). Now turn about the mandril till the slider comes horizontal, and setting the circle M eccentric by its screws P and Q, it, of course, moves the slider in the groove, and also the work with it, farther from the centre, because the two steel pieces R R, at the back of the slider, include the circle between them. The quality of eccentricity given to the ring is equal to the difference between the two diameters of the required ellipses, so that the work shall move or throw out a sufficient distance to bring the point of the tool as much beyond the circle first described, as the length of the ellipses exceed the breadth; the point of the tool will now be at one end of the longest diameter, and here we will commence to trace the curve all round. In turning the mandril round till the slider comes vertical, it must return in its groove to the place it first occupied, viz. the centre; because the circle M which guides it, is not eccentric in a vertical direction, though it is in the horizontal. In this motion, the point of the tool has described one quadrant of an ellipsis, because it gradually approached the centre a quantity equal to the eccentricity of the circle M. By continuing to turn it round farther, the circle will cause the slider to move out the other way from the centre, in its groove, until it comes again horizontal, when it will be at the greatest *throw-out*, as the turners call eccentricity; and the point of the tool will be at the other end of the longest diameter, having described one half the curve. Continuing forwards, till the slider becomes vertical, it will be eccentric again, the tool, at the breadth of the oval, having finished three quarters of the ellipses; and, in turning the next, or fourth quarter, the slider throws out till it comes horizontal, and brings the work to the position where it first set out, viz. at the greatest eccentricity, and the tool at the end of the longest diameter of the ellipse.

The reader will not, perhaps, easily recognize the simple trammel in this complicated chuck, though it has, in reality, the same movement. Thus recurring to our first idea of a board, with two cross grooves in the back of it, turning round on two fixed pins which enter dove-tails in those grooves. Suppose, that one of the pins is extended to a large ring M, the groove being proportionably widened to receive it, will have the same effect; this groove is two pieces of steel R R, which have straight edges made truly parallel to each other, and perpendicular to the length of the slider K, which carries them. The other fixed pin is represented by the mandril, and the slider K being always confined in a right line across it, has the same effect as a pin entering a straight groove.

In turning oval work, in wood, the same tools are used as for circular work, but they must be very delicately used, because the circumference of the work moves with such an unequal velocity, at different parts of its revolution, that it is liable to draw the tool in, if too much hold is taken in the first instance.

WATCH AND CLOCK-MAKING.

The term *watch* is commonly applied to pocket or portable time-keepers, and such of these as are intended for the more curious purposes, have, of late years, been carried to a high degree of excellence, both regarding their theory and execution. But in the various approaches to the present high state of improvement, no one appears to have made so great a stride at once as the late eminent Dr. Hooke, by his excellent contrivance of applying a spiral spring to the arbor of the balance, by which means effects are produced on its vibrations similar to the action of gravity on the pendulum of a clock. Since this great improvement of Dr. Hooke's, very little has been added to common pocket watches. The principal changes they have undergone has been in respect to their form, and, in this respect, the utility of the instrument has been somewhat sacrificed to the fashion of the day. Before Dr. Hooke's improvements, the performance of watches was so very irregular that they

they were considered as serving only to give the time, for a few hours, and this, in rather a random kind of way; and, accordingly, they were constructed so as to be wound twice in twenty-four hours, and to be set occasionally; and for a longer period there could be no trust in them. However, it was found to be of some advantage to carry about the time even in this incorrect way. Various attempts were made by Dr. Hooke to render their performance more regular. One method was, by applying a loadstone so as to affect the balance in the manner that gravity affects the pendulum, and this appears to be an ingenious notion; for, by the application of this, as a kind of artificial gravity, a pendulum might be made to vibrate, either in the plane of the horizon, or in any degree inclined, as well as perpendicular to it. But this scheme was found to appear better in theory than in practice, and a tender spring was next applied to produce effects analogous to the former, by making one end of it play backwards and forwards with the balance, so that the balance acted like the bob of the pendulum, and the tender spring as gravity upon it; and after various trials and changing the form of this spring to that of the spiral, it might be said to be resolved into this scheme at last.

The principles of watches thus improved, they were soon brought to a wonderful degree of accuracy by that admirable artist Mr. Tompion. They were made at first with two balances, each having the like number of teeth, and running in one another; of course, they moved in contrary directions, and, therefore, their motion could not be disordered by sudden turns or jerks of the watch. Both balances had spiral springs applied to their centres, though the pallets were fixed to one only. These curious watches appear, by various testimonies, to have been executed about the year 1658. On one of these double-balance watches, presented to King Charles the Second, was this inscription—"Robert Hook, inven. 1658: T. Tompion, fecit, 1675."—This watch appears to have been wonderfully approved of by the King, and the invention got into great repute, and was much spoken of abroad as well as at home, particularly its fame flew into France, and the Dauphin had two made for him by the hand of that eminent artist Mr. Tompion.

After these inventions of Dr. Hooke, Mr. Huygens's watch, with a spiral spring, came abroad and made a great noise in England, as if the longitude could now be found.

Mr. Huygens's watch agreed with Dr. Hooke's in the application of the spring to the balance, but Huygens's had a longer spring, and the beats were much slower; and his verge had a pinion (like the present lever-watches) instead of pallets, and had an intermediate wheel acting in the pinion so as to turn it more than once round every vibration, and to this wheel were the pallets fixed on which the crown-wheel acted. Dr. Derham has suggested that, probably, Mr. Huygens's fancy was at first set to work by some intelligence he might have received of Dr. Hooke's invention from Mr. Oldenburg, or others, his correspondents here in England.* Mr. Oldenburg vindicates himself against this charge in the Phil. Trans. Nos. 118, 129.

Dr. Derham speaks of Mr. Huygens's contrivance as being very pretty and ingenious, but remarks, that it is subject to some defects; for instance, "whenever the watch stands still, that it will not go again until it be set a vibrating, which, though it be no defect in a pendulum-clock, may be one in a pocket-watch, which is exposed to continual jogs: also, it doth somewhat vary in its vibrations, making sometimes longer, sometimes shorter, turns, and so some slower, some quicker vibrations."

We have remarked above, that the operation of the pendulum-spring, when applied to the watch-balance, is analogous to the action of gravity upon the pendulum of a clock, and which it may be necessary to offer a few words in explanation of. If the bob of a pendulum be drawn aside any certain number of degrees from its perpendicular state or point of rest, and then let freely go, the action of gravity upon it will bring it back again to its lowest point, but, as in its passage thither, it will have acquired a certain *momentum*, this will carry it up nearly as far on the opposite side the perpendicular, when the same operation will again take place; and, in this way (if the pendulum be steadily supported), the vibrations will continue for many hours without any fresh impulse being given. So, in respect to the watch-balance, if it be put into its place (independent of the wheel-work), with the pendulum-spring properly attached to it, and the outer end of this spring fixed

* As the honour of this invention has been claimed by so formidable a rival as the late celebrated Huygens, it seems due to the memory of Hooke, to state a few unquestionable facts.—That Hooke had, many years before Huygens *mentioned it*, discovered the invention, is certain, as appears by what is related in the History of the Royal Society (p. 247), where other of his inventions are mentioned: it is said—"There have been invented several sorts of *Pendulum-Watches* for the pocket, wherein the motion is regulated by springs, &c."†—‡ Waller (secretary to the Royal Society), gives some account of the Life of Hooke, and he there quotes a Letter from Sir Robert Moray to Mr. Oldenburg, dated Sept. 30, 1665, from Oxford. Sir R. Moray (addressing himself to Mr. Oldenburg), says—"You will be the first that knows when his watches will be ready (meaning Huygens), and I will therefore expect from you an account of them, and if he imparts to you what he does, let me know of it; to that purpose, you may ask him if he doth not apply a spring to the arbor of the balance, and that will give him occasion to say somewhat to you: if it be *that*, you may tell him what Hooke has done in that matter, and what he intends more." Huygens's discovery was first published in the Journal des Scavans, and from thence in the Philos. Trans. for March 25, 1675, about ten years after the above letter was written, and near fifteen years after Hooke's first discovery of it. But, according to Derham, the invention which best answered expectation, was at last executed with two balances, that both balances had the same number of teeth, which, running in each other, caused both balances to vibrate alike. These teeth were not cut in the rims of the balance, but each balance had a small wheel under it, and these wheels, running in one another, caused both to move with the same velocity, though in contrary directions, and each of these balances had its spiral spring, though the pallets were fixed to one only.

† See Sprat's History of the Royal Society.

‡ See the above, and other articles to this purpose, p. 5 and 6, of the Life of Hooke, at the head of his Posthumous Works.

fixed in its proper stud (in the pottance-plate), and the balance moving freely on its pivots. If in this state of things you draw the balance several degrees from its point of rest, and then give it free liberty, the elastic power of the spring (which must have been bent in this operation), will act upon it similar to the action of gravity upon the pendulum-bob, to bring it back to its point of rest; but, in this instance also, a certain momentum being acquired in its passage, the balance will be carried thereby nearly as far on the opposite side the point of rest, and, in this way, the vibrations will be continued awhile without a fresh impulse being given; and this experiment serves to shew in what manner the pendulum-spring enables a watch to operate upon a balance of much superior weight to what it would otherwise carry, by which a great advantage is gained, for the effects of the pendulum-spring are two-fold: in the first place, it empowers the watch to carry a balance of such weight as to acquire a sufficient momentum to resist, in a great measure, the inequalities of the main-spring and the train of the wheels, and, also, by causing an increase of velocity; as the arc of the vibration increases, the various vibrations, though different as to the quantity of the arc, are nearly brought to an equality in respect to time, or made what is called isochronal.

In respect to balance-rings, it is wonderful that the English artists should not, long since, have taken example from the French, in totally throwing aside steel balances; and no opportunity should be lost in explaining the pernicious effects of using them. It must appear obvious to every body, that the regular performance of a watch must depend on the regular vibrations of the balance, and, that whatever disturbs the latter, must, in the same degree, affect the former. And it has been found, by experience, that steel balances, in general, possess more or less of magnetism, and that most of them, on trial, exhibit a distinct polarity. Now, it is impossible that there can be any watch with a balance pretty strongly impregnated with this quality, however excellent its construction in other respects, but must be subject to great inequalities in its going, and these will be produced by a variety of causes, such as change of position of the watch; or by the wearer of it carrying any thing in his pocket, formed of iron or of steel; and, more particularly, by the near approach to any thing that itself possesses magnetism. The late Dr. Knight was well aware of this pernicious influence, many years ago, and it was a common practice with him when any gentlemen came to see his magnetical apparatus, to warn them, before they entered the room, that, if they had watches, with steel balances, in their pockets, they would infallibly be spoiled by approaching his magnetical mass.

To explain the mechanism of a watch it is necessary to refer to the *Plate*, Watch-Work, which contains drawings of a sunk pocket watch of the best construction. *Fig.* 1 represents the wheel-work immediately beneath the dial-plate, and also its hands, the circles of hours and minutes being marked, though the dial on which these are engraved is removed. *Fig.* 2 is a plan of the wheel-work all exhibited at one view, for which purpose the upper plate of the watch is removed. *Fig.* 3 is a plan of the balance, and the work situated upon the upper plate. *Fig.* 4 shews the great wheel and the pottance wheel detached. *Fig.* 5, the spring barrel, chain, and fusee detached; and *Fig.* 6 is an elevation of all the movements together, the works being supposed to be opened out into a straight line, to exhibit them all at once; *Fig.* 7 is a detached view of the balance, and what is called the escapement, in action.

The principal frame for supporting the acting parts of the watch, consists of two circular plates, marked C and D in the figures; of these the former is called the upper plate, and D is called the pillar plate, from the circumstance of the four pillars, E E, which unite the two plates and keep them a proper distance asunder, being fastened firmly into the lower plate; the other ends pass through holes made in the upper plate, C, and small pins being put through the ends of the pillars, keep all together; but by drawing out these pins, the whole watch may be taken to pieces; the pivots of the several wheels being received in small holes made in these plates, they of course fall to pieces as soon as the plates are separated.

The maintaining power is a spiral steel spring, which is coiled up close by a tool used for the purpose, and put into a brass box called the barrel; it is marked A in all the figures, and shewn separate in *Fig.* 5, with the spring in it: the spring has a hook at the outer end of its spiral, which is put through a hole, *a*, *Fig.* 5, in the side of the barrel, and rivetted fast thereto; the inner end of the spiral has an oblong opening cut through it, to receive a hook upon the barrel arbor, B, *Fig.* 5; the pivots of this arbor pass through the top and bottom of the barrel, and one of them is filed square to hold a ratchet wheel, *b*, *Figs.* 1 and 6, which has a click and retains the arbor from turning round, except in one direction; the two pivots of the arbor are received in pivot holes in the plates C D of the watch, and the pivot which has the ratchet wheel upon it, passes through the plate, and the wheel marked *b*, *Figs.* 1 and 6, with its click, is therefore on the outside of the pillar plate D of the watch; the top of the barrel has a cover or lid fitted into it, through which the upper pivot of the arbor projects; thus the arbor of the barrel is to be considered as a fixture, the click of the ratchet wheel preventing it from turning round, and the interior end of the spiral spring being hooked, this arbor is stationary likewise. The barrel thus mounted has a small steel chain, *d*, *Figs.* 2 and 6, coiled round its circumference, and attached to it by a small hook of the chain which enters a little hole, made the circumference of the barrel at its upper end; the other extremity of this chain is hooked to the lower part of the fusee, marked F, *Figs.* 2, 5 and 6, and the chain is disposed either upon the circumference of the barrel, or in the spiral groove cut round the fusee for its reception, the arbor of which has pivots at

at the ends, which are received into pivot holes made in the plates of the watch; one pivot is formed square and projects through the plate, to adapt the key by which the watch is wound up.

It is evident that when the fusee is turned by the watch-key, it will wind the chain off the circumference of the barrel on itself; and as the outer end of the spring is fastened to the barrel, and the other is hooked to the barrel arbor (which, as before-mentioned, is prevented from turning by the click of the ratchet wheel, *a b*, beneath), the spring will be coiled up into a smaller compass than before, and by its reaction will, when the key is taken off, turn the barrel, and by the chain turn the fusee and give motion to the wheels of the watch, which will be hereafter described. The fusee has a spiral groove cut round it, in which the chain lies; this groove is cut by an engine, in such a form that the chain shall pull from the smallest part or radius of the fusee, when the spring is quite wound up, and therefore acts with its greatest force on the chain; from this point the groove gradually increases in diameter, so as the spring unwinds and acts with less power, the chain operates on a larger radius of the fusee, so that the effect upon the arbor of the fusee, or the cog-wheel attached to it, may always be the same, and cause the watch to go with regularity.

To prevent too much chain being wound upon the fusee, and by that means breaking the chain or overstraining the spring, a contrivance called a guard-gut is added; it is a small lever, *e*, *Fig.* 2, moving on a stud fixed to the upper plate C of the watch, and pressed downwards by a small spring, *f*; as the chain is wound upon the fusee, it rises in the spiral groove, and lifts up the lever until it touches the upper plate, and it is then in a position to intercept the edge or tooth, *g*, of the spiral piece of metal seen on the top of the fusee, and thus stops it from being wound up any further.

The power of the spring is transmitted to the balance by means of several cog-wheels, which multiply the number of revolutions that the chain makes on the fusee, to such a number, that though the last or balance wheel turns $9\frac{1}{2}$ every minute, the fusee will at the same time turn so slowly, that the chain will not all be drawn off from it in less than twenty-eight or thirty hours, and it makes one turn in four hours; this assemblage of wheels is called the train of the watch. The first cog-wheel, G, is attached to the fusee, and is called the great wheel; it is shewn separated from the fusee in *Fig.* 4, having a hole through the centre to receive the arbor of the fusee, and a projecting ring upon its surface; the under surface of the base of the fusee is shewn in *Fig.* 5, at F, having a circular cavity cut in it to receive the corresponding ring upon the great wheel G, *Fig.* 4; a ratchet wheel, *i*, is fixed fast upon the fusee arbor, and sunk within the cavity excavated in the lower surface of the fusee. When the wheel and fusee are put together, a small click, *h*, *Fig.* 4, takes into the teeth of the ratchet *i;* as the fusee is turned by the watch-key to wind up the watch, this click slips over the sloping sides of the teeth without turning the great wheel; but when the fusee is turned the other way by drawing the chain from the spring barrel, the click catches the teeth of the ratchet wheel, and causes the cog-wheel to turn with the fusee.

The great wheel, G, has forty-eight teeth on its circumference, which take into and turn a pinion of twelve teeth, fixed on the same arbor with the

Centre wheel, H, so called from its situation in the centre of the watch; it has fifty-four teeth to turn a pinion of six leaves, on the arbor of the

Third wheel, I, which has forty-eight teeth; it is sunk in a cavity formed in the pillar plate, and turns a pinion of six, on the arbor of the

Contrate wheel, K, which has forty-eight teeth cut parallel with its axis, by which it turns a pinion of six leaves, fixed to

The balance wheel, L; one of the pivots of the arbor of this wheel turns in a frame, M, called the pottance, fixed to the upper plate (shewn separately in *Fig.* 4), and the other pivot runs in a small piece fixed to the upper part, called the counter pottance, (not shewn in any of the figures), so that when the two plates are put together, the balance wheel pinion may work into the teeth of the contrate wheel, as shewn in *Fig.* 6. The balance wheel, L, has fifteen teeth, by which it impels the balance *o p;* the arbor of the balance, which is called the verge, has two small leaves or pallets projecting from it, nearly at right angles to each other, these are acted upon by the teeth of the balance wheel L, in such a manner, that at every vibration the balance receives a slight impulse to continue its motion, and every vibration so made, suffers a tooth of the wheel to escape or pass by, whence this part is called the escapement of the watch, and constitutes its most essential part. The wheel L, is sometimes called the scape wheel, or crown wheel; its action is explained by *Fig.* 7, which shews the wheel and balance detached. Suppose in this view, the pinion *h*, on the arbor of the balance wheel or crown wheel, *i k*, to be actuated by the main spring which forms the maintaining power, by means of the train of wheelwork in the direction of the arrow, while the pallets *m* and *n*, attached to the axis of the balance, and standing at right angles to each other, or very nearly so, are long enough to fall in the way of the ends of the sloped teeth of the wheel when turned round at an angle of 45°, so as to point to opposite directions, as in the figure; then a tooth in the wheel below for instance, meets with the pallet *n* (supposed to be at rest), and drives it before it a certain space, till the end of the tooth *escapes;* in the mean time the balance, *o s p r*, attached to the axis of the pallets, continues to move in the direction *r o s p*, and winds up the small spiral or pendulum spring, *q*, one end of which is fast to the axis, and the other to a stud on the upper plate of the frame; in this operation, the spring opposes the momentum given to the balance by this push of

of the tooth upon the pallet, and prevents the balance going quite round, but the instant the tooth escapes the upper pallet, *m*, meets with another tooth at the opposite side of the wheel's diameter, they therefore moving in an opposite direction to that below; here this pallet receives a push which carries the balance back again (having as yet but small momentum in the direction *o s p r*), and aids the spring, which now unbends itself till it comes to its quiescent position, but it swings beyond that point, partly by the impulse from the maintaining power on the pallet *m*, and partly by the acquired momentum of the moving balance, particularly when this pallet, *m*, has escaped; at length the pallet *n* again meets with the succeeding tooth, and is carried *backward* by it in the direction in which the balance is now moving, till the maintaining power and force of the unwound spring together overcome the momentum of the balance, during which time the *recoil* of the balance wheel is apparent (or the seconds hand of the watch has one put on the pivot of the arbor of the contrate wheel;) at length the wheel brings the pallet *n* back again till it escapes, and the same process takes place with pallet *m* as has been described with respect to pallet *n*; thus two contrary excursions or oscillations of the balance take place before one tooth has completely escaped, which is the reason there must always be an odd number of teeth in this wheel, that a space on one side of the wheel may always be opposite to a tooth on the other, in order that one pallet may be out of action while the other is in action.

The upper pivot of the verge is supported in a cock screwed to the upper plate, as shewn at N, in *Fig.* 6, which covers the balance, and protects it from violence, and the lower pivot works in the bottom of the pottance, M, at *t*, *Fig.* 4. The socket for the pivot of the balance wheel, is made in a small piece of brass, *v*, which slides in a groove made in the pottance, as shewn *Fig.* 4, so that by drawing the slide in or out, the teeth of the balance wheel shall just clear one pallet before it takes the other; and in the perfection of this adjustment, which is called the scaping of the watch, the performance of it very greatly depends. We shall speak more fully of this in another place. The banking of the watch is to prevent the balance from being turned round too far by accidental jerks, in which case one of the pallets would be pitched upon the point of a tooth of the balance wheel, and recoil it back too far, perhaps injuring its point; this is called being overthrown. Sometimes if the balance gets turned round too far, the pallets are both turned away from the teeth of the wheel, which then runs down with inconceivable rapidity, and probably breaks the points of its teeth by striking against the pallets as they turn round; to avoid these accidents, the banking is introduced; it is a pin fixed in the rim of the balance, and therefore describing a circular arc round the edge of the cock N, which covers the balance; but the proper extent of this arc is determined by the banking-pin meeting two projecting parts of the cock, which are extended out so far as to reach beyond the circle the banking-pin moves in.

We have now described the means by which the watch keeps time, viz. that every vibration of the balance suffers a tooth of the balance wheel to escape and run down, by the constant action of the main spring; it now remains to shew the communication of this motion to the hands of the watch, which indicate the time on the dial plate. The hands are moved by the central arbor, which comes through the pillar plate and projects a considerable length; it has a pinion of twelve leaves, called

The common pinion, *w*, *Fig.* 6, is fitted upon it, the axis of which is a tube formed square at the end, to fix on the minute hand, W; it fits tight upon the projecting arbor of the centre wheel, and therefore turns with it, but will slip round to set the hands when the watch is wrong and requires to be rectified; the common pinion is situated close to the pillar plate, and its leaves engage the teeth of

The minute wheel, X, *Figs.* 1 and 6, of forty-eight teeth, which is fitted on a pin fixed in the plate, and its pinion, *x*, of sixteen leaves, which is fixed to it, turns

The hour wheel, Y, of forty-eight teeth; the arbor of this is a tube, which is put over the tube of the cannon pinion carrying the minute hand, and has the hour hand, Z, fixed on it, to indicate the time upon the dial plate. Thus, by the *cannon pinion*, *w*, which is to the *minute wheel* X, as one is to four, and the pinion *x* of this, which is to the *hour wheel*, Y, as one is to three, the hour wheel Y, and its hand *z*, though concentric with the cannon pinion and minute hand, make but one revolution for twelve of the other, therefore one turns round in an hour, and the other turns round once in twelve hours, as the figures on the dial shew.

An increase of force in the action of the main spring would alter the rate of the watch, by communicating a greater force by the teeth of the balance to the pallets. The fusee is therefore grooved in such a way, after being made in the shape of the frustum of a parabolid, that the decrease of the acting radius is always inversely proportional to the intensity of the main spring. By this admirable contrivance the effective power of the spring is at all times very nearly alike. The adjustment of the varying levers, or points of action of the fusee, is made very conveniently by a long lever with a moveable weight like a steel yard being inserted on the square of the fusee arbor which is made for the key, as will be explained more particularly in its proper place, when we come to explain the methods used by watch-makers for adjusting and finishing their watches.

It is necessary to have some regulation by which the rate of the watch's movement may be regulated, for hitherto we have only spoken of making the watch keep always to a uniform, or certain rate of motion, but it is necessary

necessary to make it keep true time. This can be done by two means, either by increasing or diminishing the force of the main spring, which increases or diminishes the arc that the balance describes; or it may be done by strengthening or weakening the pendulum-spring, which will cause the balance to move quicker or slower.

The pendulum-spring, *q*, *Fig.* 3, is fixed to a stud, upon the plate *c*, by one end, and is attached to the verge of the balance by the other.

The regulation is effected by means of what is called the curb; this is a small lever, *z*, *Fig.* 3, projecting from a circular ring, *r r*, which may be considered as its centre of motion, but perforated with a hole through the centre, large enough to contain the pendulum-spring within it; a circular groove is turned out in the upper plate, nearly concentric with the balance, and the ring, *r r*, fits into this. Both are turned rather largest at the bottom, in the manner of a dove-tail; but the ring being divided at the side opposite to the lever, *z*, can be sprung up and rendered so much smaller as to get it into the groove, but being once in the elasticity of the ring, it expands it, so as to fill the groove completely; in this state it may be considered as a lever which describes a circuit round the verge as a centre, and the end of it points to a divided arc engraved on the upper plate, at one end of which is marked F, and, at the other, S, denoting that the index or lever, *z*, is to be moved towards one or the other, to make the watch move faster or slower as its regulation requires.

The manner of its operation is thus, the end of the lever, or index *z*, continues within the circle a small distance towards its centre, and passing beneath the outer turn of the spiral spring *q*, has two very small pins rising up from it, which include the spring between them; the actual length of the pendulum-spring is therefore to be estimated from these pins to its connexion with the verge; now, by altering the position of the index, this acting length can be regulated at pleasure, to produce such vibration of the balance as will make the watch keep true time. By shortening the length, the spring becomes more powerful, and returns the balance quicker so that it will vibrate in less time; this is effected by moving the index towards F. On the other hand, turning the index toward S, lengthens the spring by which it becomes more delicate, and less powerful, returning the balance slower than before.

The old-fashioned watches have their curbs turned by a pinion, to which the watch key is applied, and it has a small dial to contain the divisions by which its motion is determined. These divisions are not of any actual value in time, but they serve to shew where the index stood, and which way it has been moved when any regulation is made. The same kind of watches usually have, instead of the ratchet-wheel *b*, on the arbor of the spring-barrel, a small wheel turned by an endless screw, to the end of which a key was applied; this was the remains of the old watch made before Dr. Hooke invented the pendulum-spring, because such a watch was necessarily regulated by winding up the main-spring arbor, and, therefore, it was left so that the possessor of the watch could effect it without recurring to the maker. A watch of this description is in possession of the writer of this article, and is, in general, similar to the watch above described; but the balance is not quite half the size of the common watch, because the vibrations of a balance without a spring are so much slower, as it had no quiescent point to return to, being merely a fly to which the maintaining power gives a smart stroke, urged in one direction, and then the next tooth of the balance-wheel destroys its motion and drives it back again, so that constantly giving it an impulse in a new direction, makes a resistance to the maintaining power, which keeps the watch to its rate, but not with any great accuracy, because the slightest motion greatly disturbs the motion of such a balance, and its small size renders it very subject to variation from any irregularity in the force of the main-spring.

Delicate watches have jewelled pivot-holes for the top and bottom of the verge, to diminish the friction. These jewels are fixed in the bottom part *t* of the pottance and in the top of the cock, each consists of two pieces, one of which has a cylindrical hole drilled through it to receive the pivot; the other is a flat piece, making the rest or stop which forms the bottom of the hole. Both stones are ground circular on the edge, and are fitted and burnished into a small brass ring, which is fastened into the cock and pottance by two small screws applied to each. The addition of jewels to a watch is a great advantage, as they do not tend to thicken the oil in the manner brass holes do, from the oxydation of the metal.

The reader is now well acquainted with the mechanism of the common pocket watches, which are in most general use; but those watches which are intended for accurate measurement of time, have some difference in their construction, chiefly in the escapement, and the balance, which, as before-mentioned, are the parts on which the measure of time depends, the others being only to actuate and record the time measured out by the balance.

It is essential to a watch which is intended to keep time with extreme accuracy, that

1st. It shall not be affected by variation of temperature; for the balance of the common watch is expanded by heat, and the pendulum-spring is relaxed by its force, both which alterations tend to diminish its rate in hot weather, and make it gain in cold weather. This defect is obviated by the compensation-balance.

2d. That the balance must, if possible, vibrate in the same time, whether it describes long or short arcs; this is called the isochronim of the balance. It is attained by a proper adjustment of the pendulum-spring, and by rendering the balance as little dependant on the influence of the maintaining power as possible, leaving it to its own free vibrations; this is effected by the escapement.

3d. That the watch shall go whilst winding-up, so as it may not lose time during that essential operation; the

the contrivance, called the going-fusee, accomplishes this.

4th. That it shall keep the same rate in all positions, therefore the balance must be truly poised on its verge.

The first of these conditions is attained by the introduction of the compensation-balance, which is a most admirable contrivance; it consists of weights instead of the solid rim of the balance, and these weights are so fixed that they approach the centre of the balance in hot weather, and recede from it in cold, just as much as is requisite to compensate for the loss or gain of force in the pendulum-spring.

Fig. 10, represents a compensation-balance such as is usually introduced into the best chronometers or time-keepers made by the English artists. It is made in the following manner:—A circular groove is turned in the flat surface of a piece of steel, and into this groove a piece of good brass is driven, and a little of the solution of borax is applied to prevent oxidation. This compound piece, being then put into a crucible, is made sufficiently hot to melt the brass, which, in these circumstances, adheres firmly to the steel without requiring solder. The face of the steel is then cleaned, and by proper application of the mechanical means of turning and filing, the superfluous steel is taken away, and the balance is left, consisting sometimes of two or three radii, A B, and a rim, C D; the external part of which is brass, and the internal part of steel; the former metal being about twice the thickness of the latter, in order to allow for the superior susceptibility of brass to steel, of any change of temperature. Some artists solder the metals together, and others plunge the steel balance into melted brass, and suffer them to cool together, but the method we have described seems to be the best.*

In this state the arcs, C D, of the rim are then cut through, and then diminished in their length, as in the figure; and near that extremity of each arc, which is farthest from its radius, a piece of brass or weight, E F, is put on, which can be slided along the arm so as to be adjusted at that distance which, upon trial, shall be found to produce a good performance under the different changes of temperature. The peculiar advantage of this balance may be explained as follows:—When an increase of heat diminishes the elastic force of the pendulum spring, the outer brass rim being lengthened by expansion more than the steel, must cripple or warp the steel, on the same principle as the warping of wood by damp, and this throws the weights, E F, nearer to the axis, and diminishes the effect of the inertia of the balance, which, consequently, is as speedily carried through its vibrations as before, though the force of the spring is diminished. And, on the contrary, when cold weather adds to the elastic force of the spring, the same weights are thrown farther out, and prevent the acceleration which would have followed. The exact adjustment of the weights is found, by trial, of the going of the machine. If it gains by heat, the weights compensate too much, and must be moved farther from the extreme ends of the circular compound bars; but if the gain be produced by cold, the spring predominates, and the weights will accordingly require to be set farther out. For it is evident that the flexure of these arms by change of temperature, will carry the weights nearer to the centre in hot than in cold weather, and the more, the greater the distance of the weights from the radius. The small screws, G H, near the ends of the radii, afford an adjustment for time, as the balance will vibrate more quickly the further these are screwed in, and the contrary will be the case if they be unscrewed or drawn further out. This is requisite in an accurate watch, it being found to be a much better method than making alterations in the pendulum-spring, because this destroys the adjustment by which our second condition, viz., that the vibrations shall be performed in equal times, whether long or short, is fulfilled. It is found, by experience, that, in every spring sufficiently long, a certain portion of it will be isochronal, whether long or short; that the length of this portion being found, if it be lessened, the long vibrations will be quicker than the short ones; and, that, on the contrary, if the length be increased, the small arcs will be performed in less time than the great arcs. This isochronal length of the pendulum-spring can only be found by experiment, and, when once determined, should not be altered on any account. Some artists taper the thickness of the spring, making it thinner at one end than the other; but, after all, if the balance is not made very independent of the maintaining power, by a proper contrivance of the escapement, the isochronal property of the spring will be overruled by the irregularities of the maintaining power, which irregularity alone requires the necessity for any such property, by diminishing or increasing the arc of vibration as the maintaining power varies in its force; for though a fusee may be adjusted, so that the action of the spring may be in every part equal; yet a watch, when it has been long in use, always has less power on the balance, which loses in the extent of its vibration, from the gradual accumulation of dirt in the wheelwork, and more from a clamminess which takes place in the oil, which is applied to the pivots, particularly that at the verge pivots; so, that, if the actual power of the main-spring is not diminished, the resistance to that power is constantly increasing, and would, in the course of years, completely put a stop to the motion of the watch.

A good escapement for a watch should only apply the impelling power to the balance at the moment when it is near the quiescent point, leaving it to finish the vibration by the combined action of the pendulum-spring, and its own momentum alone; without being influenced in the

* Mr. Harrison, in observing the effects of change of temperature of the air on his thermometer-kirbs, observed, that the brass parts became sooner affected always than those of steel, and, in order to counteract this superior susceptibility in brass, he thought it necessary, in constructing his gridiron-pendulums, to make the brass rods stouter than the steel ones, to prevent their overacting their antagonists.

the period of its return by the action of the maintaining power. This is not the case in the escapement used in the common watch we have described, which is called the crown-wheel escapement: in this, the balance is constantly connected with, and influenced by, the maintaining power, except during the exceedingly small time of the drop of the wheel from one pallet to the other, on which account the measure of time will greatly vary when the force of vibration is nearly equal, or not much greater than the maintaining impulse; this is shewn in a striking manner by urging the motion of a common watch by means of the key. If the key be pressed in the usual direction of winding up, the beats of vibration will become very slow, or even stop; and, if the pressure be made in the opposite direction, the vibrations will become very loud and quick. To remedy this defect of the crown-wheel escapement, many different kinds have been devised and employed by different artists, and with good effects: that which has been most generally employed in pocket watches is called the horizontal escapement, from the circumstance of the last, or balance-wheel, having its plane horizontal or parallel with the balance and the other wheels.

In *Fig.* 9, the balance-wheel is seen with twelve teeth, upon each of which is fixed a small wedge supported above the plane of the wheel, as may be seen by the letters A B and C D. On the verge of the balance there is fixed part of a hollow cylinder E, of steel or other hard metal, the imaginary axis of which passes through the pivot of the verge. H represents this cylindrical piece, with a notch cut in one side which nearly divides it. The wedge A, *Fig.* 9, may be supposed to have fallen into this notch. While the vibration causes the cylindrical piece to revolve in a direction which carries its anterior edge *a*, towards the axis of the wheel, the point of the wedge A, will merely rub the internal surface, and no otherwise affect the vibration of the balance than by retarding its motion by the friction of the cylinder against the point of the tooth. But when the return of the vibration clears the edge *a* of the cylinder of the point of the wedge, the wheel will advance, and the slope surface of the wedge A, acting against the edge *a* of the cylinder, will assist and impel the vibration of the balance. When the edge *a* of the cylinder arrives at the outer point of the wedge A, its posterior edge *b* must arrive at the position denoted by the dotted lines of continuation, immediately after which, the wedge or tooth B will arrive at the dotted position, and rest on the outer surface of the cylinder, where it will produce no other effect than that of retardation from friction, as was remarked with regard to the wedge A, until the returning course of the vibration shall bring the posterior edge *b* of the cylinder clear of the point of the wedge dotted in this last situation, the wedge will act on the wedge *b* of the cylinder, and assist the vibration as in the former case; but, in a contrary direction, until that edge shall arrive at the outer point of the wedge, immediately after which the leading point will fall on the inner surface of the cylinder in the first position, as was shewn in the wedge A: thus the cylinder, and the balance attached to it, receives an impulse on the edge *b*, every time a tooth escapes or enters into the cylinder, to urge it in one direction, and every time a tooth escapes out of the cylinder an impulse is given on the edge *a*, in a contrary direction.

Horizontal watches were greatly esteemed during the last thirty years, until lately when they gave place to those coustructions which are known by the name of detached or free escapements. In the common escapement, *Fig.* 7, an increase of the maintaining power, as before mentioned, increases the recoil and accelerates the vibrations; but with the horizontal escapement there is no recoil, and any increase of the maintaining power, though it may enlarge the arc of vibration, will not necessarily diminish or alter the time. It is accordingly found, that the experiment of altering the maintaining power by the application of the key, does not alter the rate in the same perceptible manner as in common watches.

The only objection which can be raised to the horizontal escapement, is the friction occasioned by the tooth of the wheel resting either within or without the cylinder. In what is called the detached escapement, this defect is remedied by introducing a detent or click to lock the teeth of the wheel; now in the interval, when the tooth in the horizontal wheel would be resting against the cylinder, this detent rests or *locks* the tooth of the wheel, and keeps it in repose, without touching the cylinder, or pallet (as it is called in the detached escapement); the balance therefore vibrates with perfect freedom, but at a certain part of its movement (near the quiescent point), a pin in the verge unlocks the detent, and the balance receives an impulse or stroke, by a tooth of the wheel dropping on a pallet through a part of every second vibration; but during a great part of its course it is free and detached, whence the name of the escapement.

A great variety of forms of escapement are in use in watches, but the detached escapement at present takes the lead among them, and it is certainly the best of any we have described. There is a class of escapements called remontoire, from the circumstance of their having a small spring near the balance, which is by the mechanism wound up at every vibration, and then the pallet of the balance presents itself and receives the force of this spring to give it the impulse for its vibration, and whilst this is performed the remontoire is wound up again for the next stroke; by this means the remontoire spring becomes the measure of the force dealt out to the balance at each time, and the irregularities of the main spring have then no effect upon the balance, because if stronger, it only winds up or charges the remontoire more swiftly, but cannot give it more power to exert on the balance, nor less if the maintaining power is diminished, because in this case the remontoire is charged more slowly, but still

to

to the same extent of force. The complexity of these escapements is a bar to their general use.

Our third condition for an accurate watch, viz. that it shall continue its motion whilst winding up, is carried into effect by the going fusee; this is one among those inventions which have proved the most useful in practice. By very simple mechanism, the main spring while the watch is going, acts on an intermediate short spring, which Mr. Harrison (the inventor) calls the secondary spring; it is constantly kept bent to a certain tension by the former, for the fusee has no communication with the great wheel except by this spring; when the watch is winding up, and the principal spring, fusee, chain, &c., ceases to act, the secondary spring, being placed on a ratchet wheel which is hindered from retrograding by a click, continues the motion of the great wheel without alteration. Other contrivances have been proposed and executed, to make time-pieces go while winding up, but none which like this combines the advantage of simplicity, and the property of providing a supplementary power, which is equal to that of the main spring when its action ceases. And it is to be observed, that the utility of the going fusee, which has induced manufacturers to introduce it into all good watches, even of the common kind, is peculiarly important in those time-pieces which have not the power of setting themselves in motion, as is the case with the best modern escapements, because the balance is the greater time completely detached.

Figs. 21, 22 and 23, are representations of a going fusee taken to pieces; in *Fig.* 23 it is supposed to be seen from below, and shews the under sides of the parts, while 21 shews the other faces; *a*, *Fig.* 23, the small ratchet, like the common fusee, fixed upon the arbor of the fusee F, and sunk into an excavation in the large end of the fusee, its plane is therefore the same with the end of the fusee; the clicks and springs, *b b*, *Fig.* 21, for this ratchet, are fixed on the plane of the large or perpetual ratchet, L, which has a stationary click applied to its teeth to prevent it ever returning in a direction contrary to the direction of the motion of the great wheel; therefore when the fusee turns round by the draft of the chain, the clicks *b b* of the small ratchet, causes the perpetual ratchet L to turn round with it; but when the fusee turns in the opposite direction for winding it up, the perpetual ratchet remains stationary by its click, which is situated on an arbor pivoted between the plates of the watch; G, in both figures, is the great wheel, and *Fig.* 22 is a horse-shoe spring, bedded between the perpetual ratchet and the great wheel, a circular groove being turned in the plate of the large wheel, as shewn in *Fig.* 21, at *n*, or it might be made in that of the large ratchet, or partially in both, to form a bed or box for this secondary spring; the pin *f*, at one end of the spring, is inserted into a corresponding hole in the bed of the wheel, and the other pin, *s*, into a similar hole perforated through the perpetual ratchet at *g*; this spring thus connected with both the great wheel and perpetual ratchet, would produce no other effect than to attach them together and make them like one wheel, if the horse-shoe piece was not elastic, in which case the large ratchet would be superfluous, and the effect produced would be that of an ordinary simple fusee and ratchet; but the piece in *Fig.* 22, is of a spring temper, and its elasticity small enough to be acted upon by the main spring, so as to make two pins *s* and *f*, at the ends, approach each other; and in this situation it is that the secondary spring is said to be wound up, in which it continues whenever the watch is going.

In this state it is evident that whatever power the fusee exerts upon the great wheel must be through the medium of the secondary spring, which therefore becomes wound up or charged with as much force as is required to turn the watch. Now suppose the power of the fusee removed, or its action to cease, and at the same time the ends of the spring which the fusee operated upon by the medium of the perpetual ratchet, to be supported by any fixed object, the effort of the spring to extend or discharge itself will act between this fixed object and the pin *f* which connects it with the great wheel, to turn the wheel round for a time, in the same manner as before. Now on applying the key R to wind up the watch, the clicks *b* of the small ratchet *a*, which turns with the fusee, slip over the sloping sides of its teeth, and relieves the great ratchet L from the power which caused its motion, and it endeavours at first to accompany the fusee by the exertion of the secondary spring to unbend itself, but a tooth of this ratchet meeting the stationary click, prevents its retrograde motion farther than the interval between two teeth. In consequence of this opposition to the great ratchet's temporary motion, by the action of its click, the pin *f*, at the other end of the secondary spring, pulls at its hole in the great ratchet wheel G, and draws it away from *s*, which is stationary; or in other words, draws the great wheel round in a contrary direction, and with a force, equal for the time to that of the original maintaining power by which the two pins were made to approach each other. The reason of the pin *f*, in *Fig.* 21, being made to project both ways across the end of the secondary spring, is, that the remote end beyond may move in a little circular aperture made through the plane of the great wheel behind, *Fig.* 23, which aperture allows the two ends of the spring to approach and recede steadily, and the length of the aperture is determined by the quantity that pin is drawn by the main spring towards the pin before; there is an equipoise in their intensities.

Repeating Clocks are such as by pulling a string, &c., are made to strike the hour, quarters, &c., at any time. These clocks are the invention of a Mr. Barlow, about the year 1676. This ingenious contrivance soon took air, and various artists set their heads to work, and several different methods were contrived to effect such a performance, and hence arose the various ways of

of executing repeating work. This invention had been practised in larger movements only, till James the Second's reign, at which time it was applied to watches, (commonly called pocket clocks,) and hence arose some contention respecting the right to the invention. Mr. Barlow, who no doubt was the inventor of the principle, engaged Mr. Tompion to execute the first repeating watch, for which Mr. Barlow purposed to obtain a patent. Mr. Quase, an ingenious artist, had entertained some thoughts of executing such a piece, but had laid it by, until the talk of Mr. Barlow's patent renewed his former thoughts, which he then brought to effect. This being known among the watch-makers, they pressed him to hinder Mr. Barlow's patent; accordingly applications were made at court, and a watch of each invention produced before the king and council. The king upon trial of each of them, was pleased to give the preference to Mr. Quase's, of which notice was soon after given in the Gazette. The difference between these two inventions was, Mr. Barlow's was made to repeat by pushing in two pieces, one on each side the box, one push gave the hour, and the other gave the quarter. Mr. Quase's was made to repeat by a pin that stuck out near the pendant, which by thrusting in gave both the hour and the quarter, as is now done by the pendant.

The mechanism of the repeating watch is extremely complicated, and would far exceed our limits to explain it. It contains all the mechanism of the common watch, and arranged in the same manner, except that it is all crowded to one side, to make room for the striking movement; this has a small spring box with a train of wheel work, which actuates the hammer that strikes the hours and quarters upon a bell, which is fastened on the inside of the watch case and encloses the work, but without touching any part of it, it is screwed into the case. The numerous detents which govern the number of strokes the hammers will make, are situated beneath the dial plate, along with the motion or dial work, shewn in *Fig.* 1. On pushing in the pendant of the watch, it drives before it a lever, which has a small chain attached to it, and this draws round a small wheel, about which it is wound, and thus winds up the striking spring, and at the same time sets off the detents, the spring now causes the hammers to strike the hour and the nearest quarter.

Striking watches are such, as beside the proper watch part, for measuring time, have a clock part for striking the hours, &c. These are real clocks, only moved by a spring instead of a weight, and are properly called pocket clocks. The difference between the striking watch and the repeater is, that the former has the spring barrel of the striking movement wound up at the same time with the main spring of the other part, and at every hour the dial work discharges the striking part, and causes it to strike the number of hours. The objection to these watches is, that the power necessary to move the hammers through the whole day, obliges the springs and striking train to be so large that it crowds the going parts too close, and renders the repairs, as well as making, of such watches most difficult and expensive. One great distinction between a striking-watch and a repeating-watch is, that in the striker you wind up the main-spring of the striking-part once in twenty-four hours, and which supplies its power occasionally through that space of time; but, in the repeater, you wind up the striking-spring by pushing in the pendant occasionally.

In the early stages of the business, watches were of simple construction, and very imperfect in their performance; and every artist was compelled, from necessity, to make almost the whole watch himself; but, in the present state of the art, it is divided into a great number of branches; and each, by devoting himself exclusively to that branch, becomes more expert and accurate than any one could hope to be who undertook to do the whole himself; and when the trade is subdivided, the expense of tools adapted to each operation becomes trifling, whereas few individuals could afford to purchase all the tools and engines necessary to form the whole machine.

The general use of watches among a commercial people has a great effect in introducing strict habits of punctuality, and economy of time; and when this is once understood, as it is in our own country, the manufacture and repair of watches becomes an immense trade, employing many thousand individuals, who, by uniting ingenuity, industry, and experience, are able to make the parts of them at so low a price as is truly astonishing.

We must observe, that the mechanism of watches is made in the villages of Lancashire, where the most minute operations are divided into a separate and distinct trade, each of which is provided with its proper tools and engines for expediting the business, and making several of the parts at once.

A stranger will be much surprised at being told, that to make a single watch, by the same means as are at present in use, would require various tools and engines to the value of more than two thousand pounds; but as these are distributed among a great number of different trades, the expense to each is moderate, and the advantages derived from their use is very great, both in the economy and accuracy of the work.

To enumerate the different trades would be a list as numerous as there are parts in the watch; but, in a general way, they may be divided into the following; though this division is not to be considered by any means as invariable.

1st. *The spring-maker* makes the springs to all lengths, thicknesses, and breadths; curves them, and tempers them.

2d. *The chain-maker.* This is a very curious art from the very minute parts of which it is composed; he makes all kinds which can be required.

3d. *The fusee-cutter* employs very curious engines to form the spiral grooves on it, and as the expense of these requires

requires him to be a man of more capital than some others, he frequently keeps other engines for cutting the balance wheels and other wheels; but this is sometimes a separate branch, as follows:—

4th. *The wheel-cutter* employs engines to divide and cut all the cog wheels, but his workmen generally confine themselves to one kind of wheel.

5th. *The dial-plates* are enamelled by a distinct trade.

6th. *The case-maker* makes all kinds of cases in gold, silver, or metal. These last are gilt by the water-gilder.

7th. *The watch-glass maker.*

8th. *The hands*, and many other small parts, also chasing and ornamenting the cock and upper plate, are the work of as many different hands.

9th. *The pinions* are made by the wire-drawer, of any size or number of teeth.

10th. *The movement-maker* makes the plates; he collects the wheels, fusee, &c., from the different workmen, fixes the wheels upon their arbors, callipers, or sets out the watch, and puts the wheels in the frame, but in a rough way, and only as a preparation for

11th. *The finisher*, or, as he is generally termed, the maker. He polishes the teeth and steel parts, finishes and turns the pivots, and fits them to their holes; adjusts all the parts, together with the escapements, and completes the whole business. It is this department of watch-making that we particularly intend to explain.

All the parts of a watch, made in the most accurate manner, may be purchased, ready prepared by the above trades, at many shops in the metropolis. The most extensive and established of these is Mr. Samuel Fern's, Newgate Street.

The principal tools necessary to a watch-maker, are, as follows:—

A small bench-vice to hold the tools, so called from its being screwed or fixed to the bench.

A pin-vice to file up pins and hold various small works.

Pliers, of various sizes and forms.

Wire-nippers for cutting off wire pins.

Drills, of various sizes. The smallest are made from needles or fine wire, and are held in a drill-stock, which has a screw nose that will hold any size. Also, drill-bows and breast-board to cut them.

Files of all descriptions, as flat, square, round, crossing-files, &c. &c.

Gravers and turning-tools, of various kinds; several pieces of Turkey stone; oil-stone dust to polish steel; and brushes to clean watches with.

Small hammers for riveting wheels upon the arbors, and various small drifts, punches, sets, &c, for the same purpose; also, small stakes or anvils to place the work upon. These latter are held in the bench-vice.

Five-sided broaches, of various sizes, to open or enlarge pivot holes to the proper dimensions, and round broaches to burnish the insides of the holes.

A turn-bench, or, a watch-maker's turn, which is nearly the same, except in dimensions, is indispensable for forming the pivots and all parts which are circular, see *Fig.* 11, of *Plate* CLOCK-WORK. The watch-maker must be provided also with a variety of arbors for fitting collets, wheels, &c., to turn them on (see *Fig.* 12) ferrules, which are small pulleys to fix upon pins, arbors, and various works, to turn them round by the bow with a catgut band. Screw ferrules are the same, but have clams to bite the work like a vice; these must be exceedingly small to be used for turning the verge-pivots, its bow must be very slender, and work with a horse-hair. See a full explanation of all these kind of tools under TURNING.

A balance-tool, which is a small lathe with a mandril and collar, for turning the rim of the balance circular. See *Fig.* 8.

A pair of callipers, with an index adjustible by a thumb screw, of use for trying if a wheel is placed at right angles to its arbors, or, what is called, in the flat; and, also, if it is perfectly concentric, or in the round. See *Fig.* 16, *Plate* WATCH-WORK.

Spring-tongs to take up the parts, for they should never be touched by the fingers. See *Fig.* 11.

Inside and outside gauge for measuring work. See *Fig.* 15. Also,

A magnifying-glass, to view the works. Some artists have a pedestal or stand to support it, while others apply it to their eye.

Spring-tool, for coiling up the main-spring to put it into its barrel. See *Fig.* 19.

Pendulum-spring blueing-tool. This is to hold the spring over a candle to temper it, and has a small wheel held on the spring to prevent it from warping, or from getting away. See *Fig.* 12.

The balance-wheel pitching-tool, *Fig.* 13. Of its use more will be said.

The pitching-tool, *Fig.* 18, is for ascertaining the distances at which the pivot-holes of any wheel and pinion should be situated, to make their teeth engage properly with each other (called, running the depths).

An adjusting-tool, for fusees, with sliding weights to suit any given maintaining power of the main-spring of the watch. *Fig* 20.

A fusee tool, for cutting the groove in the fusee, or for rectifying it after being cut by the maker.

Screw-drivers, of various dimensions; and a

Poising-tool, to try the balance; it is perfectly equipoised. See *Fig.* 17.

The movement of a watch complete may be procured at Mr. Fern's, or many other shops, for the trifling sum of seven shillings. This is truly surprising when we reflect what it consists of, viz., the plates and pillars, fitted together parallel to each other; the spring-barrel, but without a spring; the fusee, great wheel, and all the wheels complete. They are fixed fast on the arbors, but the pivots are not formed, neither is the groove of the fusee cut. The balance-wheel is not fitted upon its arbor, because the pivot must be turned first,

first, neither is the balance, but both wheel and balance are provided, and also the verge, and they only require to have pivots formed.

For a small increase of expense, the watch-maker may have the movement in a more perfect state; viz. the pivot holes determined, and then he has only to fit the pivots to them, and make the escapement; but as it will be interesting to explain the manner of doing this, we will describe the method of fitting the wheels together, or what is called callipering the movement; though it is to be observed, that it is far better to let the movement-maker do this, because having done one by the process we shall describe, he makes perhaps one hundred other movements of exactly the same dimensions, and then he has only to drill off the pivot holes of all the hundred, from the first one so ascertained, and the wheels being made to the same dimensions, will all fit together without further trouble.

We will suppose our watch to be of the following numbers:

The fusee $7\frac{1}{2}$ spirals, great wheel 48 teeth, revolves once in four hours.

The centre wheel, *pinion* 12 leaves, *centre wheel* 54 teeth, revolves once per hour.

The third wheel, *pinion* 6 leaves, wheel 48 teeth, revolves 9 times per hour.

The contrate wheel, *pinion* 6 leaves, wheel 48 teeth, revolves 72 times per hour.

The balance wheel, *pinion* 6 leaves, wheel 15 teeth, revolves 576 times per hour.

The balance has two pallets, and will make 17,280 beats per hour.

Watches are made of many different numbers in the train, but a general rule to obtain their ultimate products, viz. the number of beats per hour, is as follows: Divide double the product of all the wheels, from the centre wheel to the balance wheel inclusively, by the product of all the pinions with which they act, the quotient will be invariably the number of beats that the watch in question makes in an hour; and again, if we divide this quotient by 3,600, the number of seconds in an hour, the latter quotient will be the number of beats in every second, which may be carried to any number of places in decimals.

It must be remarked that in this rule no notice is taken of the wheels and pinions, which constitute the *dial work*, nor yet of the great wheel and central pinion with which it acts; the use of the former of these is only to make the hour and minute hands revolve in their respective times, and must not be the same in all watches, to make the motion of the hour-hand to that of the minute hand as 1 to 12, and the use of the great wheel and its central pinion is to determine in conjunction with the number of spirals on the fusee, the number of hours the watch shall continue to go at one winding-up of the chain from the barrel of the main spring; all these wheels and pinions therefore, it will be perceived, are unnecessary to be taken into the account in calculating the beats per hour. The reason why *double* the product of the wheels specified is taken into the calculation, is this, that one tooth of the crown wheel, completely escapes the pallets at every two beats or vibrations of the balance. An example will render the general rule perfectly intelligible. Let us take for example, the numbers of a common watch as above stated.

Now omitting the great wheel and its pinion of 12, we have $54 \times 48 \times 48 \times 15 \times 2 = 3,732,480$ for double the product of the specified wheels; and $6 \times 6 \times 6 = 216$ for the produce of the specified pinions, also $\frac{3732480}{216} =$ 17,280, are the number of beats in an hour, and $\frac{17280}{3600} = 48$ the exact number of beats per second; accordingly Mr. Emerson says that this watch makes about $4\frac{3}{4}$ beats in a second, which it does very nearly. The number of spirals on the fusee is $7\frac{1}{2}$, therefore $7\frac{1}{2} \times 4$ the number of hours it makes one turn, $= 30$ is the number of hours that the watch will go at one winding up: the dial work $\frac{48}{12} \times \frac{48}{16} = 4 \times 3 = 12$ likewise shews that whilst the first cannon pinion of 12 goes twelve times round, the last wheel of 48 goes only once, whence the angular velocity of two hands carried by their hollow axles, are to each other as twelve to one.

Many watches are called stop watches, from the circumstance of their having a small detent with a spring, which can at pleasure, by touching a stop at the outside of the case, be made to press against the run of the contrate wheel. These watches always have a hand on the dial to indicate seconds; the contrate wheel, the arbor of which carries the seconds' hand, must therefore revolve 60 times per hour, or once per minute; the following numbers are proper for such a watch; it will go 30 hours:

Fusee 6 turns, great wheel 60 teeth, revolves once in five hours.

The centre wheel *pinion* 12 leaves, wheel 64 teeth, revolves once per hour.

The third wheel, *pinion* 8 leaves, wheel 60 teeth, revolves 8 times per hour.

The contrate wheel, *pinion* 8 leaves, wheel 60 teeth, 60 per hour, or once per minute.

The balance wheel, *pinion* 6 leaves, wheel 15 teeth, 600 per hour, or 10 per minute.

The balance has two pallets, and will make 18,000 beats per hour, or 5 per second.

Having thus given the numbers and the rule for calculating the movements of any watch, we must return to the method of callipering the movement. The watch-maker first measures the distance between the inside of the two plates of the watch, with his inside gauge, see *Fig.* 15, *Plate* WATCH-WORK, the two ends, *a b* and *c d*, of which are equally distant from the centre joint *e*, and therefore when the points *a b* of one end are opened to any extent for an inside gauge, and set by the screw *g*, the points *c d* of the other end are adapted to the same opening, to measure outside work or lengths, the spring *h* keeps them shut up as far as the screw *g* allows.

He

He now prepares to turn the pivots; for this purpose he fixes his screw ferrule, *Fig.* 13 of *Plate* Clock-Work, upon it, then passes the gut of the bow round the groove of the ferrule, and mounts the arbor in his turn, *Fig.* 11, thrusting the centres A B towards each other, till the arbor, which enters holes in the ends of the centres, runs without shake, and there he fastens them by the thumb screws C D; the turn is now held in the bench vice by the lower part E E of the frame, the rest F G H, is next adjusted, and all is then prepared for turning with the graver, which the watch-maker applies to the work by his right hand, holding it on the rest G, while he turns the work round by the bow held in the left; when he has by these means reduced the end of the arbor to a fine pivot, he polishes and grinds it fine by a small quantity of oil-stone dust applied with oil on a piece of steel, which he holds against the pivot; as it turns round he uses the gauge, *Fig.* 15, to make his arbor of the right length between its shoulders; having reduced the pivot to size, he brings it to the length by pulling the point marked K into the turn, this is filed away with a notch, *d*, to expose the end of the pivot which fits into a hole made through the part beyond the notch; a file can now be applied in the notch to cut off the pivot to the proper length, and then to file it to an obtuse cone, which is the shape the ends of pivots are usually left.

All the pivots being made in this manner, the wheels must be fitted on to those arbors which were not previously done by the respective makers; these are the third wheel and balance wheel, because these are so near the ends of their arbors that the pivots cannot be turned after the wheels are put on; the arbors have a small brass collet fastened and brazed upon them, this collet is turned away to fit exactly the centre hole in the wheel, and a shoulder is left to fit the wheel up against, and when put on, it is riveted; this is done by resting the collet upon the stake, *Fig.* 14, which is a small piece of steel with a hole through it to admit the arbor, but affords a resting place to the collet; this is held in the bench vice and the wheel put in it; the set which is a punch with a hole drilled in it, is put over the end of the arbor which comes through the wheel, and a few gentle blows with the hammer rivets it on all sides at once, by expanding the collet in the hole in the wheel.

He now tries the wheel in his callipers, *Fig.* 16, *Plate* Watch-Work; the ends of the points *a a*, or beaks, have several small holes made in them to receive the pivots of any arbor; they will open to any extent, and can be fastened by the clump *c*, or its screw *d;* the arbor being mounted between them is twirled round to try the wheel *h* if it is truly centred upon the arbor, and also if its plane is truly perpendicular thereto, or if it is true in the flat, as the workmen say; it is ascertained by holding some fixed object against it. It is usual among watch-makers to hold a small straight ruler across the blades *a a* of the callipers, to prove if the wheel runs true upon its arbor; but some callipers are provided with a small finger or index, made of two pieces, *e f*, jointed together, and one of them, *e*, united to the callipers by a joint, by which means the point of *f* can be brought to meet a wheel of any size. When it is applied as in the figure, it proves whether the wheel is in the square, for if on holding it up to the light the wheel appears to advance and recede from the point of the finger, it shews an error which must be rectified by what is called *setting;* to do this the workman observes that side of the rim of the wheel which comes nearest to the finger *f* in its revolution, he then removes the wheel and places it in a tool called a mandril, *Fig.* 15, *Plate* Clock-Work, which is similar to a cup or inverted bell; it is held in the vice and its circular edge supports the rim of the wheel, leaving its centre hollow, and its arbor completely detached: he now with the pen or beak of the smallest riveting hammer, strikes an extremely light blow on that arm of the wheel which is opposite to the faulty side of the rim, this bends or sets the arm so as to put the wheel in the square with its axis; it is after this tried in the callipers again, to prove that the setting is sufficient, and if not, it is repeated. In setting a wheel, the workman is particularly attentive to avoid twisting the rim of the wheel; this he does by bedding it fairly on the edge of the mandril, and taking care not to strike its rim when he hammers on the arm, because it is only intended to bend the arm, leaving the rim a true plane as it was before the setting, but its inclination altered so as to make it exactly perpendicular to the arbor, of which the trial in the callipers is the most delicate test.

All the wheels being finished in this manner, are prepared for putting in the watch, by drilling the holes for their pivots in the plates; to find the proper situation for these holes, a pitching tool, *Fig.* 18, is used; it is in reality two small turns, A A, B B, united together by a joint, C; each is provided with its pair of centres, *a b* and *c d*, and fixing-screws to hold them wherever they are placed; by means of a screw, E, which passes through the turn B, and operates against the other, A, the two can be separated on their joints C to any required extent; but it is plain in this movement, that its centres, *a b* and *c d*, will always continue parallel to each other. A spring, F, tends always to shut the two together, as its two ends are connected to the turn B by two links, *g g*, and the middle of the spring, which is convex, presses against the turn A, and tends always to press them together, as far as the screw E will permit. The use of this tool is to ascertain the distance that any wheel and pinion should be placed asunder, for the teeth to work into each other in a proper manner; to effect this the wheel is placed between one pair of centres, *a b* or *c d*, and the pinion between the other pair and the screw E is adjusted until they will work into each other with freedom, and without any material looseness or shake between the teeth; in this state, it is evident that the points *a b* or *c d*, formed at the extremities of the respective centres, will

will exactly represent the distance that the pivot-hole of the wheel and pinion should be placed asunder, and these points may be used as a pair of compasses, to mark off the distances on the plates of the watch; and this being done for every wheel and pinion successively throughout the watch, will ensure their being pitched truly.

The centre wheel is known to be placed in the centre of the watch plates; a hole is therefore first drilled in the centre of the pillar plate, D D, *Plate* I, to receive the arbor of the centre wheel, not its pivot, because the arbor of this wheel passes through the plate to receive the cannon pinion, to carry the minute hand, as before described; the pivot hole, after drilling, is opened out and enlarged to the proper dimensions by a round broach; this is a round piece of steel, like a wire, but rather tapering; it is forced into the hole, and turned round at the same time, by which it enlarges the hole without cutting out any metal, and therefore it burnishes and hardens the interior surface of the hole, so that it will wear much better than the soft brass would, if merely drilled.

The great wheel and centre wheel are now put in the pitching tool, and by it the distance proper for the great wheel to work in the centre wheel pinion is ascertained, and then one point, *a*, of the tool being set in the centre hole of the plate, an arch is described with the other, *c*, and in some point of this arch the great wheel pivot must be placed; this point being found (by trial), so that the wheel and fusee will be clear of the other works, is drilled; then the spring barrel is tried, not by the pitching tool, but by placing it in any situation where it will be free from the other wheels, and here its pivot hole is drilled. The pitching tool next determines the distance of the third wheel from the centre wheel, and also the distance the contrate wheel is to be from this. The callipering of the pillar plate is now finished, and when the corresponding pivot holes are drilled in the upper plate, the watch may be put together; now it is essential for the wheels to run well, that the arbors must be exactly perpendicular to the plane of the plates; to ensure this, the holes in the upper plate are drilled by means of the upright tool, shewn in *Fig.* 9, *Plate* Clock-Work; this is a kind of lathe, which is held in the bench vice, and its spindle turned by a bow, in the same manner as the turn, before described. In this figure, which is an elevation taken from one side, A B represents a steel spindle mounted in a brass frame, C D E, the part E of which is held in the bench vice; the spindle has a neck formed on it, which is accurately fitted into a socket formed in the part D of the frame; the opposite end, A of the spindle, is supported by the point of a centre screw, F, which can always be screwed up, to make the spindle run without shake; the end of the spindle which projects through the collar, or socket D, is formed into a screw, by which any kind of chuck can be screwed on; thus this tool is exactly the same as a small lathe. The chuck which is represented as fixed on in the figure, is a flat brass plate, G, which has three grooves cut through it, extending nearly from the centre to the circumference; these grooves are arranged at equal distances round the centre; three thumb-screws, such as is shewn at *a a*, pass through each of these grooves, and each is tapped into a piece of brass, *b*; now by shifting these screws along in their grooves, the three pieces of brass, or clams, *b b*, may be removed to any distance from the centre, and the screws, *a a*, will confine them in any position; each clam has a small piece of brass, *d*, which by means of the screw *e*, can be made to bite or clamp the edge of the watch plate, H; the biting parts of all these clams being equally distant on the face of the chuck, the watch plate, H, will of course be parallel thereto, and therefore perpendicular to the length of the spindle, A B; this is hollow for some distance from the chuck, to receive a piece of steel wire, which is accurately fitted into it, as shewn by the dotted lines, K, and can be slid backward and forward by means of a small bolt at I, which comes through a cleft in the spindle; the extremity, *r*, of this wire, which is called the centre-pin, is formed to a very delicate centre point, which can be protruded any distance from the face of the chuck, but always preserves its point accurately in the centre line of the spindle, and therefore perpendicular to the chuck G.

The manner of using the upright tool is this; the watch plates, H L, are pinned together, and the centre point, *r*, being advanced considerably beyond the chuck, its point is applied to any of the pivot-holes made in the pillar plate H, by the process before described; the three clams, *b b*, are then set, so that they will touch the circumference of the plate, by advancing them respectively towards the centre a proper distance, and fixing them by the screws *a a*; the other screws, *e e*, being now turned close to the jaws, *d d*, of the clams, and they hold the edges of the plate H fast between them, as is shewn in the figure. By this means the watch frame is fixed, so that its plane is perpendicular to the axis of the spindle A B, and the pivot hole, which is intended to have another drilled opposite to it, is exactly in the centre line of the spindle; the rest M, is now set in a proper position before the watch plate, and a drill being held over it, is presented to it, while the plate and spindle are turned round by means of a bow, the band or cat-gut of which encompasses the small pulley, N, on the spindle; the drill (as is well known to turners) is easily guided to pierce the watch plate in the exact centre line of the spindle, because if it is not presented to this centre, its point will scratch a small circle upon the plate, and when the drill is set in the centre of this, it will be in its correct position. Make a pivot hole in the upper plate, L, exactly opposite to that in the pillar plate, M, which is guided to its place by the centre point, *r*, of the spindle; when one pivot hole is thus drilled, the watch plate is very quickly shifted to another pivot hole, which is brought opposite

opposite to the centre, in the same manner as we have before described. It is by means of the upright tool that the cavities are made in the plates of the sunk watches, to receive the centre wheel and third wheel; these are turned by a graver at the same time of fixing as when the respective pivot holes are drilled, and the circular excavations will therefore be exactly concentric with the pivot holes; the excavation for the centre wheel is very shallow, few except the flattest watches having any at all; the cavity for the third wheel is cut quite through the plate, and the pivot is supported by a cross bar, fixed by two little screws on the under side of the plate, and extending across the centre of the hole. It should have been observed, that this cross bar is fitted before the movement is put in the upright tool, a hole is drilled through it in continuation of the pivot hole, this bar is removed, as is also the upper plate, and the movement is fixed in the tool by the edge of the pillar plate, instead of the upper plate; the excavation for the third wheel is then turned out, but the cross bar, when fixed up again by its screws, will certainly be concentric with this cavity. The upright tool will hold the watch by either pillar or upper plate, just as is required, and will produce the same effects in either case, but it is best to hold that plate which is to be operated upon, because the pillars of the frame are not then liable to strain. In this manner a hole is frequently turned to cut through the upper plate, to admit the top of the spring barrel to pass through it, the upper pivot of the barrel arbor is then supported by a cross bar or piece, called the barrel cover; this method admits a greater length of barrel, and of course a broader and stronger spring. The upright tool which we have described, is that which is generally used by watch-makers for finishing the works, and occasionally enlarging or deepening the excavations, or for boring out one of the pivot holes large enough to receive a jewel; but the professed movement-maker, who constantly employs an upright tool, has it fixed with a wheel to be turned by the foot, and generally has a slide-rest fixed before the work, to hold the tool, instead of trusting to the unsteadiness of holding it in his hand upon the rest N. The upright tool is frequently attached to the watch-maker's lathe, and this is perhaps the best method.

The fusee, centre wheel, third wheel, and contrate wheel being put in the watch in this manner, the pottance is fitted by temporary pins to the upper plate, in such a position that it will not interfere with the rest of the works, which being determined it is rivetted fast, the cock is then screwed on with the steady pin, and by fixing the upper plate alone in the upright tool, the hole to receive the jewel to form the socket for the upper pivot of the verge is bored, and will be truly perpendicular to the hole which has been previously drilled in the pottance for the jewel of the lower pivot; then without removing the plate from the upright tool, the cock is taken off, and a hole bored through the upper plate, to permit the axis of the verge to pass through (this hole is afterwards filed square, to suffer the balance wheel to reach the upper pallet), at the same time the circular groove in the upper plate, which is to receive the ring of the curb, is formed.

The balance wheel is next fitted; one of its pivot holes being drilled in the centre of the small dovetail slider of the pottance. Then to make the pivot hole in the counter pottance exactly the same distance beneath the upper plate, so that the balance wheel arbor shall be exactly perpendicular to the verge, the balance wheel pitching tool, *Fig.* 13, WATCH-WORK, is employed. It consists of a brass plate, *a b c*, with an index, *d e*, moveable on a centre, *d*, by means of the screw *f*, against the point of which it is constantly pressed by the spring *g*; it is in fact a pair of compasses, adapted to this particular purpose; the straight edge *b* of the plate *a b c* is applied flat against the under surface of the upper plate, and the screw *f* being turned, adjusts the point *e* till it comes exactly opposite the pivot hole in the slider of the pottance. The tool being now applied in a similar manner to the counter pottance, marks the proper height for the pivot hole to be made therein, which is accordingly drilled with a large hole, to receive a pin called the follower, at the end of this the pivot hole itself is drilled; the balance wheel is now tried in its place; its pivots having been made in the same manner as the other wheels, and if on trial it is found to come on its right place, so that its arbor does not interfere with the contrate wheel arbor, the counter pottance, which was only fitted in a temporary manner, is rivetted fast. In this trial, it will be seen if the teeth of the contrate wheel works well with the balance wheel pinion, and if not, it must be rectified, by *setting* the contrate wheel in the same manner first described, by the mandril, *Fig.* 15, and a proper acting punch or drift; this bends the arms so as to throw the rim and teeth of the wheel nearer or farther from the balance wheel pinion, as is required to make it work properly; it is scarcely necessary to add, that the wheel ought to be tried in the callipers, that it runs square every time it has been set.

Having thus described the means of putting in all the wheels, which is called fitting the movements, we must attend to the manner of fitting and adjusting the spring barrel and mounting fusee. A spring must be procured from the tool shop, which is of such a breadth as to fit the spring barrel, and a proper length and stiffness to have a sufficient power to actuate the watch; the knowledge for the proper strength for the main spring of a watch of any dimensions, can only be obtained by experience and practice, which teaches the artist that a watch of certain dimensions will require a main spring, the length, breadth, and thickness of which he measures by accurate gauges. These he takes with him to the tool shop, and selects, from an immense number, a spring which suits them; as an additional proof, it is weighed. Those who are not

possessed of this experience, may find it necessary to try two or three springs, before one is met with of the proper strength, and which will act with a due degree of regularity.

It has been asserted, that a spring will act more regularly, and be less liable to give under friction among the coils, if the breadth be gradually diminished from the exterior to the interior, and that the friction of the sides of the spring against the ends of the barrel will thereby be greatly diminished. The spring arbor must be strong in proportion to the force of the spring, particularly at the pivots, the front one of which must be thick enough to admit of being squared, to hold a ratchet, or small serrated wheel, at the outside of the pillar plate, shewn at *b*, *Fig.* 1, the teeth of which ratchet must be strong enough to hold the arbor in any situation to which it is turned, which it does by means of a click, attached by a screw to the exterior surface of the pillar plate of the frame; the spring arbor has a strong hook formed out of its substance at the middle, within the barrel, on which hook a hole made near the interior end of the spring is hitched, while the exterior end is rivetted to the circular side of the box; hence it is not difficult to conceive, that when the spring fills the box in its relaxed state, and has its coils most close at the rim of the barrel, it may be coiled up close to the arbor in the centre, or in other words, it may be *wound up* by two different methods; either the barrel may be held fast, and the arbor be turned backward by its ratchet, or by a key fitting its square; or otherwise, which is the general and better practice, the ratchet may be suffered to retain the arbor in its place, and with it the interior end of the spring; and the barrel itself, to which the exterior end is rivetted, may be turned forwards by the chain attached to it by a hook at one end, and wound round it, as seen at *Figs.* 2 and 6. We have said the latter method is the better, and the reason is, that when the greatest and smallest forces of the spring are adjusted to the shape of the fusee, or rather the fusee to them, the ratchet cannot be altered without deranging this adjustment. The arbor is turned in the turn bench, with pivots and shoulders sufficiently remote from each other, to reach the interior faces of the watch-plates, but to have just so much play endways as will prevent friction, and the chain must be long enough to fill the spiral grooves of the fusee. Care also must be taken, that the depth or side of the barrel must be nearly equal to the effective length of the fusee, otherwise the chain will be liable to slip off at the ends of it.

The bottom of the barrel is soldered fast, and has a large pivot-hole against which an inner shoulder of the arbor rests, and the lid is turned so large, as to be capable of being forced or sprung into a receptacle turned for it round the inner part of the edge of the circular rim of the barrel, in which situation it rests against a corresponding inner shoulder of the arbor, and completes the barrel; when this adjustible end is to be taken off, for the purpose of examining or taking out the spring, a slight stroke at the remote pivot of the arbor will force it out of its place: some skill is necessary for putting the spring in the barrel, in the manner which is usually done by the country watchmakers; but it is very easily performed by using the tool represented by *Fig.* 19; it consists of a brass frame, A D, which is held in the bench vice by the projecting piece D; C is a small steel spindle extending across the frame, provided with a small handle, E, by which it is turned round, and it is prevented from turning back again by a ratchet wheel which is hid behind the plate F; *a* is a small click, which engages the teeth of this ratchet and prevents its retrograde motion; the projecting parts of the frame, A D, immediately above the spindle, are cut with two clefts to receive a parallel bar, G, which has liberty of motion in these clefts either endways or up and down, and it has a steel beak, *g*, projecting from it. At the extreme end of the spindle, *c*, a small hook is formed, corresponding with the hook upon the barrel arbor of the watch; upon this hook the interior end of the spring is caught, and the hook at the outer end of the spring is hitched upon the projecting beak, *g*, of the slider G. Now by turning the handle E, the spring can be wound up to any required compass, and the ratchet *a* prevents its return; the spring is thus wound up so small as to enter the box or barrel which is applied to it, and the click *a* being relieved, suffers the spring to *expand* itself and fill the barrel: the hook at the extreme end now enters the hole prepared at the side of the barrel for its reception, this being done, the barrel arbor is put in its place, the cover of the barrel put on, and it is ready to take its place in the watch.

The fusee is next prepared; as we have before mentioned, the experienced watch-maker knows what proportion the two ends of this fusee should bear to each other, to compensate for the irregular action of the main spring he has chosen; if he has *not had* these opportunities, the following method may be used to determine it. A rough estimate for the power of the spring must be first made, by coiling the chain in a proper direction a few times round the barrel, till it is nearly all wound up, the arbor being held in a ratchet or vice, and then by suspending a weight to the sphere end, such as will just pull the barrel two or three times round from its relaxed state, this weight will denote the smallest power, which suppose to be three ounces; then add a heavier weight, such as will uncoil as much more of the chain as may be supposed, from a previous measurement, to be sufficient to fill the fusee, and note it, which we will again suppose to be seven ounces, for the greatest power of the spring; now this proportion of three to seven may be taken as a guide for the respective diameters of the conical piece of metal called the fusee, which is introduced to equalize the varying power of the spring, by causing the chain to act, as it were, with a succession of levers, of different lengths reciprocally proportionate

portionate to the power of the spring in any given situation, so that when the power is great, it is pulling by a short lever, and vice versa. The piece of solid metal intended for the fusee, must be drilled through the centre, and opened with a broach, and then have a steel arbor of considerable strength driven tight into it, by which it is turned into a conical, or rather a paraboloidal shape, generally having its thicker end somewhat smaller than the diameter of the spring barrel, and the other end reduced in proportion, according to the supposition of 3 : 7, but sometimes in a greater ratio, without reckoning the thickness of the chain; the length of the fusee must be shorter than the pillar, by as much as will admit the great wheel and ratchet, with the centre wheel behind them, to be introduced between it and the plate at one end. Room is left for a contrivance for stopping the revolutions when the spirals are filled with the chain, called the guard-gut, because the first watches had a cat-gut instead of a chain. The fusee is prepared in this manner by its maker, who cuts the spiral groove in it in some cases, by a very curious engine for the purpose; but the watch-maker will generally have to rectify this groove, to suit the irregular action of the individual spring which he has adapted to the watch.

After the groove is cut, a pair of strong pivots may be turned on the fusee arbor, the pivot-holes in the plates opened by a pivot broach, held perpendicularly with respect to the faces of the plates, and the fusee introduced into the frame, parallel to the spring barrel arbor; the extreme end of the groove at the large end of the fusee, is made much deeper for a very short distance, and a pin being fixed across the groove in this deep part, serves to attach the chain to the fusee by passing round it the hook formed at the extremity of the chain. The chain, perhaps, is the most surprising piece of workmanship in the whole watch, considering the very minute parts of which it is composed; every inch in length of some watch chains contains thirty links, one half of which number are formed of two plates opposite to each other, while the other half of the number are single links, to unite the double links together, by means of a pin or rivet put through the end of every link, and passing through all the three; thus one inch in length consists of fifteen double and fifteen single links, making forty-five plates, and thirty pins to unite them together, in all seventy-five pieces; yet a chain of four inches in length, polished and finished, is sold for less than one shilling; some of the fine chains for a repeating watch, have near double this number of links in an inch. If now a square be made, either on the front or back pivot of the fusee which must project through the plate, accordingly as the watch is intended to be wound up in the face or behind, and if a key be inserted upon it, the spring may be wound up, and it will appear whether or not the chain is too long, and how much, which may accordingly be altered. Hitherto the work has proceeded on a supposition that the fusee has been turned of a paraboloidal shape, and that the spring is perfect at the two extremities as well as at all the intermediate degrees of tension; but it yet remains to be proved, by mechanical adjustment, that these coincidences have been effected without material subsequent alterations in the length of the chain and shape of the fusee.

These adjustments are made by means of the adjusting-tool, *Fig.* 20, which is made of a long steel wire A B, upon which two sliding weights D and E are fitted, and at one end is a clam or vice C, which is screwed up by a nut F; by means of this clam the tool is affixed to the square at the end of the fusee arbor where the key is applied to wind up the watch; this is done when the fusee is mounted in its place in the watch, which being held so that the fusee arbor is horizontal, and the lever of the adjusting-tool is turned round until it becomes horizontal also. The weights are now gradually moved along the wire A B, until, by trial, they are found to be an exact counterpoise to the spring, previously wound up by means of the ratchet on the barrel arbor. Such balance being effected, the spring may be wound up by the adjusting-tool, used as a key, till the seventh spiral at the top, or small end of the fusee, be filled with chain; in which situation, if the weight of the tool still constitutes an exact counterpoise to the power of the spring, it is to be presumed, that the spring is properly fixed with respect to its quantity of intensity by its ratchet; but, if in the latter situation of the tool it turns out to be more than a counterpoise, either the spring is of too low an intensity in the present situation of its ratchet, or the fusee is too small at the small end, or both may be so circumstanced. On the contrary, if the tool is not a counterpoise for the spring when wound up, either the spring is set too high by the ratchet, or the small end of the fusee is too thick; a few successive trials of similar adjustment for opposite ends of the fusee, by an increase or decrease of the intensity, being gradually given to the spring by the means of turning its ratchet, will generally determine whether the failure in the adjustment is occasioned by the mounting of the spring, or the curve of the fusee, and the former may be rectified by the ratchet, or the latter altered by a detached tool to run in the groove, as it revolves in the turning bench, if a fusee-engine is not at hand; though it must be confessed, that some experience in this business will greatly facilitate the determination of the proper means of final adjustment. We will now suppose the spring fixed, and the fusee adjusted by the tool, so as to render the maintaining power precisely the same at the bottom and top of the spiral groove; the adjustments must next be made for all the intermediate turns of the helix, successively, by means of the same adjusting tool, with the weight of the adjusting tool unaltered, the spring arbor also resuming at every trial, its original position which we will suppose to have been marked on the holding tooth of the ratchet.

When the spring is good, and the fusee approaching to

to a conical shape, it will be found, on trial, that the maintaining power is too great for the tool of adjustment to balance before it is wound up half way; in consequence of which increase in the maintaining power, the fusee must necessarily be again put into the fusee-engine, and have its groove deepened, so as to make a parabolic curve, instead of a straight line from the top to the bottom of the fusee. After this alteration, the frame of the watch must be remounted, the spring coiled up again to its determined position, and the weights of the adjusting-tool kept unaltered in its situation on the wire. The intermediate grooves in the helix may not yet be found all correct in their effects throughout the whole length of the fusee, but the adjusting tool will detect the particular places where the power predominates; which places, when marked, may be again altered in the fusee-engine, and the parts replaced in the frame; when, after three, four, or perhaps more alterations of the fusee, and adjustments of the spring, at length the effect produced by the power of the spring is the same, whatever part of the fusee be actuated by the chain. The accuracy of this adjustment is of the utmost importance, and should be minutely attended to, otherwise the watch may be made to vary its rate of going on each successive hour of the day, by reason of the irregularity of the maintaining power, unless, indeed, such a consequence be obviated by the nature of the escapement, or other contrivance, which ought not to be depended upon while there is a fundamental remedy. The escapement of the common watch is such, that any increase in the maintaining power very materially affects the going of the watch: hence it is evident, that whenever the original main-spring of a watch happens to be broken, or by any means altered, another spring, though of the same dimensions, ought not to be substituted, as is often injudiciously done, without a corresponding alteration in the fusee is found necessary by a trial of the adjusting tool.

If the chain should be broken, and its length at all altered by the repairs, the mounting of the ratchet must be altered to suit it, because an alteration in the length of the chain has just the same effect as letting down or taking up the ratchet of the spring.

During this labour of adjusting the fusee to the spring, it will occur, that the chain might be wound up beyond the end of the fusee if it were turned more than seven times and a half round, on which account a small piece of soft steel, equal in diameter to the small end of the fusee, independently of the claw or projection piece, is usually driven on the fusee arbor, and fastened to the end of the fusee at *g*, *Fig.* 2.

We will now suppose our watch furnished with a maintaining power and a train of wheel-work, it only remains to provide it with an escapement, balance, pendulum-spring, and their appendages; we have supposed our watch of the common construction, having the crown-wheel escapement, the operation of which we have minutely explained; but, although this escapement is extremely simple, it is susceptible of many degrees of goodness, or imperfection, by the variation of the few particulars of its construction. We shall, therefore, briefly describe that construction, which long experience has sanctioned as approaching near to the best performance that can be obtained from the common escapement.

Fig. 8, represents it in what are esteemed its best proportions, as it appears when looking straight down on the end of the balance arbor or verge. L is the centre of the balance and verge. M N are the two pallets, M being the upper pallet, or the one next to the balance, and N being the lower one. O P are two teeth of the crown-wheel, moving from left to right; and Q R are two teeth on the lower part of the circumference, moving right and left. The tooth P is represented as just escaped from the point of pallet M, and the lower tooth Q as just come in contact with the lower pallet N. The escapement, however, should not be quite so close, because a slight inequality on the teeth might prevent it from escaping at all; for if Q touch the pallet N before P has quitted M, all will stand still. This fault will be corrected by withdrawing the wheel a little from the verge by shortening the pallets.

The proportions are as follow:—The distance from the points of the teeth, that is, of O P, Q R, and the axis L of the balance is one-fifth of the distance between the points of the teeth. The length L m, or L n, of the pallets is three-fifths of the same distance. The pallets make an angle m L n of ninety-five degrees, and the front P x, or leading edge of the teeth O P Q R make an angle of 25° with the axis LX of the crown-wheel. The form of the back of the teeth is of no importance, as they have no action on those parts, it is only necessary for them to be so curved at the back that the pallet M, in returning, will not interfere with the back of the tooth P, and this being ensured, as much substance as is practicable should be left for strength.

From these proportions it appears, that the pallet M may *throw out* by the action of the tooth P, and the momentum of the balance, till it reaches r, 120 degrees from L X, the line of the crown-wheel axis; for it can throw out till the pallet N will strike on the leading edge of the tooth Q, whereas it should only be acted upon by the point of the tooth. The leading face, as before stated, is inclined 25° to C L, to this, therefore, add n L m = 95°, and we have X L r = 120. In like manner, N will throw out to s as far on the other side. From 240° the sum of these angles (viz. s L X and X L r) take the angles of the pallets (n L m) = 95°, and there remains 145°; fix the greatest vibration which the balance can make without striking the front of the teeth. This extent of vibration supposes the teeth to terminate in points, and the acting surfaces of the pallets to be planes, directed to the very axis of the verge. But the points of the teeth must be rounded off a little for strength, and to diminish the friction on the face of the pallets. This diminishes the angle of escapement

escapement very considerably, by shortening the teeth; moreover, we must by no means allow the point of the pallet to bank or strike on the foreside of the teeth; this would greatly derange the vibration by the violence and abruptness of the check which the wheel would give to the pallet. This circumstance makes it improper to continue the vibration much beyond the angle of escapement. One third of an angle, or 120°, is, therefore, reckoned a very proper vibration for an escapement made in these proportions. The impulse of the wheels, or the angle of escapement, may be increased by making the face of the pallets a little concave, preserving the same angle at the centre. The vibration may also be increased by pushing the wheel nearer the verge; this would also diminish the recoil. Indeed, this may be entirely removed by bringing the front of the wheel up to L, and not making the acting faces of the pallets N M a radius, but a parallel to the radius and behind it, *i. e.* by placing the pallet so that its acting face may be where its back is just now. In this case, the tooth will drop on it at the centre, and lie there at rest while the balance completes its vibration. But this would make the pitching (as the stroke on the teeth is called), almost unavoidable. In short, after varying every circumstance in every possible manner, the best makers have settled on a escapement very nearly such as we have described. Precise rules can scarcely be given, because the law by which the force acting on the pallets varies in its intensity, deviates so widely from the balance-spring, especially near the limits of the excursions.

To prepare the escapement, the watch-maker first turns pivots to the verge, and fits them very delicately to the jewelled pivot-holes, previously made in the pottance and cock by the means before described; but it should be observed, that all good watches have jewelled pivot-holes for the verges. In these cases, holes of considerable size are bored in the pottance and cock, by the upright tool, and the jewel is fixed into a steel keep or ring, which is fitted into these holes, and held therein by two very small screws. The steel balance is now fitted and rivetted upon the small brass collet which is fixed on the verge, and turned to fit in the same manner as the rest of the wheels were; it is then tried in the callipers, if it turns true, and, if not, it is set square by bending or setting its arms in the same manner as any other wheel; if it should not be true in the round, which, however, cannot happen if the turning has been truly done, it is rectified by the balance-tool, *Fig.* 8, *Plate* CLOCK-WORK. This tool is a small turning spindle, such as we have before described of the upright tool; at the end of it a chuck *h* is fixed, and against it a small brass ring *n* is attached by two screws; in the centre of the face of the chuck a slight hollow is turned, and the balance *o* being placed with its arms against the face of the chuck, the ring *n* is screwed against it but very lightly, so that its position can be adjusted till the pivot *n* of the verge is found to run perfectly true when the spindle A B is turned round; the screws are then made fast, and hold the balance fast to the chuck, that its rim may be turned true, and brought to its intended form by the graver held over the rest M. It is plain, that this process might have been performed in the turn, but from the extreme delicacy of the verge-pivots, which will scarcely bear turning themselves, hence is the necessity for the balance-tool.

The chuck is made to unscrew from the end of the spindle, and various other small chucks are screwed on for different purposes, as cleaning and burnishing screw-heads, turning the ring of the index for regulating the pendulum-spring, &c. It is, in fact, a small lathe, which the watch-maker uses for turning any article which the turn will not command.

Some watch-makers have small triangular bar lathes, which are very complete, and serve very conveniently for all purposes of upright tools, balance-tool, &c.—(See a description of such a lathe in our article TURNING.)

Before the pendulum-spring is attached to the verge, the balance is tried in the balance-poising-tool, if it is equally heavy on all sides; for if this is not the case, it will greatly injure the performance of the watch when laying in different positions: the balance-poising-tool, *Fig.* 17, *Plate* WATCH-WORK, is a square brass plate *d d*, on which are erected two small standards *a b*; the latter is firmly fixed to the plate, while the former slides in a groove by means of the screw *c*. To adapt the distance between the standard, to the length of the verge, which is laid upon them in the manner shewn by the figure, its pivots rest on two small straight edges at the top of the standards, which being made sharp on the edge like a knife, and the pivots rolling on them, have scarcely any friction, and it will soon be ascertained whether the balance has any preponderating side; if so, it must be rectified by filing away a small quantity from the inside of the rim. The pallets of the verge are now filed up to their proper length, according to the proportions we have given. In this the watch-maker is usually guided only by his eye, but we would advise watch-makers to work by a gauge, such as is shewn by *Fig.* 14, which will measure to the $\frac{1}{1000}$th part of an inch, if requisite; this is the invention of Mr. Pennington, and a full explanation of its various uses will be found at the end of this article. It is sufficient here to say, that it would give the dimensions of the smallest parts of the escapement in decimals of an inch, therefore, by measuring the distance between any two teeth of the balance-wheel, every part of the escapement may be made by the proportions we have given.

The balance-wheel is prepared by filing up its teeth to sharp points. The teeth are cut by the wheel-cutters in an engine for the purpose, which forms the straight or leading edges to the teeth, and these must never afterwards be touched by the file, because of the danger of reducing one more than another, and thus rendering the intervals between the teeth unequal; the back of the teeth alone must be filed away to make them properly sharp. The manner of proceeding is this:—having rivetted

vetted the wheel on its arbor, tried it in the callipers, and set the back of it to a true square, the watch-maker puts it in the turn, and while he turns it round with the bow, holds a piece of Turkey-stone over the rest, and applies it to the teeth of the wheel as they pass by; this grinds them all to one exact length, but makes them blunt; then he takes out the wheel, and, holding it in his finger and thumb, files away the back of the teeth, successively, till they come to sharp edges, so that looking at the end of the arbor, he cannot see the ends or edges of the teeth to look of any width, and by this he knows them to be sharp enough. But he is very careful not to file them too much, as that would shorten the teeth, and then the certainty of having them all of one length would be lost, which is very essential to the performance of the watch, because every short tooth will give the balance a less impulse and will escape too soon, while every long tooth will give too great an impulse; and these successive variations would completely destroy that regularity in the vibrations of the balance which is necessary to make a watch keep good time.

The balance-wheel is now put in its place, as is also the verge, and the cock screwed on; then taking the upper plate alone with these parts, viz., the balance-wheel and verge in their places, the watch-maker tries the escapement by turning round the balance-wheel, and he examines how it escapes. If it has too much drop, that is, if one of the teeth quits its pallet before the opposite tooth meets with its pallet, the wheel will, in this case, drop or suddenly advance forwards, until the opposite tooth meets the pallet; this space or drop should be as small as possible, so as to be sure it will escape; but if the trial shews it to be too great, it must be remedied by advancing the wheel nearer to the verge. This is done by filing away the face of the slides of the pottance. If, on the other hand, the wheel is too near the verge, its teeth will be engaged by both pallets at once, in which case it will be locked, and have no motion at all; the workman avoids this by making his slider too wide at first, and diminishing it very cautiously until the drop is diminished to the proper quantity. But if he should carry it too far, the only remedy will be to make a new slider, or else set the balance-wheel back upon its arbor, by setting it in the manner we have before described of the contrate-wheel, but this will be very troublesome, because of making the teeth true again.

The wheel being scaped, the next adjustment is to make the balance-wheel-axis point exactly to the verge. This is tried by listening to the sound of the escape, and if it seems louder from one pallet than the other; or, if the glass shews that the wheel acts more upon one pallet than the other, the slider must be adjusted till they come to an equality; and here it must be observed that if one pallet is longer than another, or, if the teeth of the balance-wheel are not all of a length, and true in the square, also its axis placed truly perpendicular to the verge; any of those defects will prevent the escapement acting truly and equably on both pallets, and it will be extremely vexatious to discover the fault. All these things must, therefore, be carefully made, and tried by callipers, balance-wheel pitching-tool, &c., as before described. Then the slider being duly adjusted, all the work will come true, and the watch will scape well.

The adjustment of the slider is very conveniently made in the French watches by means of a screw which comes to the outside of the watch, and, therefore, may be adjusted when the watch is going without taking the watch to pieces, and this is often a great convenience in repairing a watch.

Having thus fitted the escapement, the pendulum-spring is prepared by attaching the interior end of its spiral to a small collet or ring which is fitted upon the lower side of the same collet of the verge to which the balance is rivetted. This ring is fitted upon the collet with sufficient friction to make the attachment, but admits of being twisted round the collet to adjust the spring required.

Pendulum-springs of all possible sizes may be obtained at the tool-shops, and the watch-maker has nothing to do but to blue them by holding them over the flame of some small-coal. In the choice of a pendulum-spring, proper for his watch, the watch-maker must be guided by experience, both as to the number of turns, size, and strength; but it will always be found best to have them long, and make a great many turns, because the spring may have more thickness and strength, and will be more elastic than a short spring, which must be extremely delicate, or it will be too powerful for the balance, and make it vibrate too quickly. Between these extremes the choice must be made, either by the experience of the workman, or he must select one at random to make a trial of. He first fixes the interior end of it into the hole made in the collet which fits on the verge, then, putting this on, he tries it to its place to see if the spiral comes free and proper; and, if not, he bends it as he wishes by a small pair of pliers. The spring is now taken out and tempered, or blued, by holding it over lighted small-coal in a tool.

Fig. 12, consists of a circular plate B, to which is affixed a small handle A, by which it is held over the candle; and to confine the spring down on the plate a small wheel *e* is fitted on the end of a detent *c d e*, which is connected with the handle by a joint *d*, and the wheel is always pressed towards the plate by a small spring *f* acting under the tail of the lever *c d e*. The operation of bluing the spring is simply placing it on the plate B, and suffering the wheel to rest upon it by the spring, this holds the spring and keeps it flat while it is heated, until the workman perceives through the arms of the wheel that the spring is turned to a fine blue colour; it now is of what they call a spring temper, and is so elastic that, if bent, it will always return to the same position, and it cannot in this state therefore be *set* or bent so as to alter its figure; whence is the necessity of trying it into its place before bluing, not to determine the effect it will have on the watch, because

because this is altered by the bluing which renders the steel more elastic. It is only tried to fit it and bend the curves to the intended shape. That part where the regulator or curb operates upon it must be bent to an arch of a circle struck from the centre on which the curb moves. The pendulum-spring is now fitted on, and put into its place, the end being pinned into the stud on the plate, then the watch-maker puts the works together, mounts up the main-spring, and tries it by winding up the watch. He knows how many beats his watch should make in a second, by calculation, and he counts them for a few seconds by another watch or a pendulum, and this adjustment is quite sufficient to determine the length of the spring from the stud to the verge, leaving it to be perfected by the adjustment of the curb. The workman now finds if his pendulum-spring is the proper strength, and, if it is not, he must put it aside, and fit another to it, observing if the watch vibrates too slowly, and has a great recoil, the spring must be changed for a stronger or a shorter one, and *vice versa*; he can increase the strength of it very materially, if the watch should vibrate too slowly, by shortening the spring, that is, by drawing it farther through the stud, and pinning it in another place, so as to have a turn less of the spiral in action between the stud and the verge; on this account, the watch-maker should chuse his spring long enough, as he can so readily shorten it to any required strength; but if he should have it too short and strong at first, he will have no remedy but to change it. By these means the watch is roughly put together and got into action, but the final adjustment to it remains to be made, and this is the most delicate part of the whole business.

In the adjustment of the pendulum-spring, the first and most essential condition is, that the watch shall be in beat; this means, that the quiescent point to which the pendulum-spring will incline the balance to rest, shall be exactly intermediate between the two points of escape, or in other words, that the two extremes of the angle of escapement shall be equally distant from the quiescent point; to effect this, most watch-makers depend upon their ear to ascertain if the beating of the watch be equally loud on either pallet, and the time between the beats be equal; but this criterion is not so correct as might be wished, because an inequality in the beats may arise from other circumstances, viz., the different lengths of the pallets, or from the dovetails of the pottance-nose not being duly adjusted, as we have before explained: but if the artist is convinced that all these things have been accurately determined, he may depend upon his ear to inform him if the watch is in beat. The best method of trial will be to hold back the contrate-wheel, so that the maintaining power has no action on the balance; if it is a stop-watch this will be extremely easy, but if it is not, a stout bristle should be thrust between the arms or teeth of the contrate-wheel, which will effectually stop the motion of the watch; then examining with the glass if the pallets are both completely detached from the teeth of the balance-wheel, this will be also shewn by shaking the watch. If the balance vibrates very small arcs, with apparent freedom, and relief from the escapement, now suffer the balance to come to rest; this will, of course, be its quiescent position, which must be marked by scratching on the upper plate opposite one of the arms of the balance, or any other mark upon it, then applying the finger to the contrate wheel, and pressing it round very slowly, at the same time feeling or retarding the motion of the balance by holding something against it until one of the pallets is felt to escape. The place where the arm or other mark on the balance now stands is to be marked on the plate; then continue to press the contrate-wheel forwards till the other pallet escapes, which place is likewise to be marked, and if these two marks are equidistant from the point of rest, the balance is properly in beat; if not, it is out of beat, and must be rectified accordingly. To do this, the balance is taken out, and the collet of the pendulum-spring, which is fitted on the verge, is twisted round upon its fitting, by holding the collet fast in pliers while the balance is turned round by the finger and thumb in such a direction that when the balance is put in again, the quiescent point will fall in between the two extremes of the angle of escapement, as marked on the plate by the experiment. In making the trial, care must be taken to move the contrate-wheel so slowly by the thumb as to retard the motion of the balance by holding something against it, so much as to give the balance no impulse, that the mark may be the precise point where the tooth escapes from the pallet. Without this caution, the angle of vibration, instead of the angle of escapement, would be marked, though both ought to be equally distant from the quiescent point when the watch is truly in beat.

Watch-makers, in general, are not very anxious respecting the angle of vibration in the common watch. They seldom use any means to increase or diminish this, though they conceive it to be a point of perfection if a watch *crosses well*, that is, if it describes a vibration of full 120 degrees, or one-third of a circle; they try this by holding a pin on the watch-plate, in such a position that one arm of the balance, when in vibration, comes as close as possible to it without touching; then, if another arm, at the opposite side of the vibration, comes to touch the same pin, or comes close to it, the watch is said to cross well, because this proves that it vibrates very nearly one-third of a circle, the arms of the balance being that distance asunder, or it may be tried by the banking-pins in the balance. The angle of vibration will depend conjointly upon the quantity of the angle of escapement, and the strength and elasticity of the pendulum-spring, compared with the maintaining power which actuates the teeth of the balance-wheel; the angle will, therefore, be regulated, either by increasing the maintaining power, or by diminishing the elasticity of the pendulum-spring, the former cannot so easily be done: it is, therefore, customary to change the pendulum-spring, if the arch of vibration should be

so different from 120° as to render it indispensable. But, as we have before observed, watch-makers are not very anxious respecting the angle of vibration, and many watches will keep time extremely well, though their angles of vibration differ very widely.

The watch is now finished, and only wants a trial of a few days to bring it to true time by means of the regulating-curb, moving it one way or the other, according as the watch gains or loses, and it operates, as has been before described, by increasing or diminishing the acting length of the pendulum-spring, causing the balance to vibrate quicker or slower. The regulator should have sufficient range to alter the rate of the watch as much as twenty minutes per day, that is, that the watch should gain that time in a day when the index is set at the end S of the scale, more than when it stands at the end marked F; and if the maker gives it this allowance, the owner of the watch will have the means of regulating it to time, as the change of season or the gradual accession of dirt in the works, and change in the oil, alters its daily rate.

We shall conclude this article by a description of an instrument invented by Mr. Pennington for taking dimensions of the parts of watches, which, in its applications, would be extremely useful to the trade, by enabling the watch-maker to send his orders and have the parts made in the most accurate manner exactly to the dimensions he requires. A view of it is given in *Fig.* 14, of the *Plate,* where *a a,* represents a plate of brass, upon which is screwed a piece *b b,* and likewise a steel spring *c.* The space between the piece *b b,* and spring *c,* is dovetailed, as is the slip *d d,* and the spring *c* causes it to slide with a gentle stiffness. Upon the piece *b b* is screwed the piece of steel *g,* and upon the slip *d d* another piece of steel *f,* the sides of which are close together, when the index points to zero, and the end of the sliding slip *d d* is made narrow, and the end of it is exactly even with the plate *a b.* This end of the sliding slip is made narrow, as represented at *d,* for the convenience of going through a hole, &c. This slip *b b* is divided into inches, and each into fifty parts, and upon the pieces *d d* is a vernier, which shews the space between the two steel pieces *f g,* and likewise how far the end of the slip *d d* projects beyond the end of the plate *a b,* and thus the dimensions of any thing put between those steel pieces will be determined; and in order to determine the inside dimensions, the ends of the piece *g* and *f* are, when close together, just 0,05 inches, so that in gauging the inside of any thing 0,05 inch must be added. The projection of the slip *d d* will determine the depth of any thing, which will be found very useful. If this gauge was universally used it certainly would be of great benefit, and it is to be wished that, in time, a watch-maker would use this gauge as a carpenter does his rule.

This gauge is well adapted for giving the proportional diameters of wheels and pinions, and for giving the proper distances of their centres.

The method of giving the proportional diameters of wheels and pinions, is this:—Suppose a wheel of sixty-four teeth, and a pinion of eight leaves, and the diameter of the wheel to be 1.256 inches, what will be the diameter of the pinion, as the diameter of wheels and pinions are not in proportion to the number of teeth; Mr. Pennington has found, by long experience, that, by adding $2\frac{1}{4}$ to the number of teeth in the wheel, and $1\frac{1}{2}$ to the number of leaves in the pinion, and using these numbers instead of the real number, will be found very near the truth. Now, to give the diameter of a pinion of eight leaves to a wheel of sixty-four teeth, as aforesaid, must be done by the Rule of Three, and the statement will stand thus, 66.25 : 1.256 : : 9.5, that is, 64, with the addition of 2.25 is 66.25, and 8, with the addition of 1.5, is 9.5.—To give the proper distance of their centres having the number of teeth, and diameter of the wheel, and the number of leaves in the pinion, add the number of the wheel and pinion together, 64 and 8, will be 72; take the half of this, and say, as 66.25 : 1.256 inches : : 36.

By this means, in drawing callipers of movements for watches, the diameters, as well as the number of teeth in the wheels and pinion may be marked upon the calliper's plate, which would supercede the use of a gauge for each wheel; thus far this method has the advantage of the sector, which only determines the proportional diameters.

Of the invention of Pendulum-Clocks.—In tracing back the history of clock and watch-work, it soon becomes obscure, as the instruments spoken of in ancient history, as having been applied to the purpose of measuring time, were of a very different nature from those we now call clocks and watches. "It is probable," says Dr. Derham, "that in all ages some instruments or other have been used for this purpose. But the earliest we read of is the dial of Ahaz, concerning which little of certainty can be said. The Hebrew word properly signifying degrees, steps, or stairs, by which we ascend to any place. Among the Greeks and Romans there were two ways chiefly used to measure their hours. One was by clepsydra, or hour-glasses; the other, by the solaria, or sun-dials. The clepsydra appears to have been a vessel filled with water, with a small hole in the bottom of it, which was set in the courts of judicature, by which the lawyers pleaded. This was, says Phavoninus, to prevent babbling, that such as speak ought to be brief in their speeches. As to the invention of these water-watches, which were, no doubt, of more common use than only in the law courts; the invention of them is attributed to P. Cornelius Nasica, the censor.

"Scipio Nasica, Pliny calls him, and saith, Scipio Nasica was the first, that, by water measured the hours of the night as well as the day. This was about one hundred and fifty years before Christ. The other way of measuring the hours, viz., with sun-dials, seems from Pliny and Censorinus, to have been an earlier invention than the last. Pliny says, that Anaximander invented dialing, and was the first that shewed a sun-dial at Lacedæmon;

Lacedæmon; he flourished about the time of the prophet Daniel. But these are not very much to our purpose, being not pieces of clock-work. In the next place the Doctor takes notice of a few horological machines of which he met with an account, these, whether pieces of watch-work or not, the reader may judge for himself. The first is that of Dionysius, which Plutarch commends as a very magnificent and illustrious piece. But this might be only a well delineated sun-dial. Another piece is that of Sapor, king of Persia; Cardan saith, "it was made of glass; that the king would sit in the middle of it, and see its stars rise and set." But we do not find whether this sphere was moved by clock-work, or whether it had *any regular* motion. The last machine we shall mention in this account, is one described by Vetruvius, which seems to have been a piece of watch-work, moved by an equal influx of water. In the French edition of Vetruvius may be seen a cut of it. This machine performed various feats, such as sounding trumpets, throwing stones, &c.; but what comes most to our purpose, was the use made of it to shew the hours (which were unequal in that age) through every month of the year. The inventor of this curious machine was one Ctesibius, a barber's son of Alexandria; which Ctesibius flourished under Ptolomy Euergetes, and might be contemporary with Archimedes." Having given a concise account of the ancient methods of measuring time, we shall now come to some particulars which more nearly relate to the present business. Clock and watch-work is thought to be an invention of much later date than the forementioned pieces, and to have had its beginning in Germany, within these three hundred years. It is probable that the balance clocks and watches might have their beginning there, or that watch and clock-work (having been long buried in oblivion), might be revived there; but that watch and clock-work was not the invention of that age, we can prove by two instances to the contrary, of much earlier date. The first example is the sphere of Archimedes, who lived about two hundred years before Christ. We have accounts of this from Cicero, and an accurate description is given of it by Claudian; from whence it appears, that in this sphere the sun and moon, and other heavenly bodies had their proper motions, and that these motions were effected by some enclosed spirit. What this enclosed spirit was, we cannot tell, but suppose it to be weights or springs with wheels or pulleys, or some such means of clock-work, which being hidden from vulgar eyes, might be taken (at least in a poetical way), for some angel, spirit, or divine power.

Dr. Derham mentions an instance of ancient clock-work from Cicero, who gives the account, that Posidonius had contrived a sphere, whose motions were the same as those of the sun, moon and five planets in the heavens. That it was a piece of clock-work cannot be doubted, if it be considered that it kept time with those celestial bodies, imitating both their annual and diurnal motions; which we may conceive, from the description, it did. It may rather be supposed that these machines could not be in common use, but were considered as rarities at that time.—Though on the other hand, in two such ages as those in which Archimedes and Tully lived, the liberal arts were greatly encouraged.

After these times, barbarism came on, and the arts and sciences became neglected, so that little worthy remark is to be found till towards the sixteenth century, and then clock-work was revived in Germany; and because the ancient pieces are German work, it has been supposed by many to have been invented anew in that country. But who was the inventor, or in what time does not appear. Dr. Derham speaks of a stately clock which stood in his time in his Majesty's palace, at Hampton-court, whose inscription shewed it to have been made in the time of Henry VIII. in the year 1540. This clock shewed the time of the day, and the motion of the sun and moon through all the degrees of the zodiac, together with the matters depending thereon, as the day of the month, the sun and moon's place in the zodiac, moon's southing, &c. He also speaks of the arrangement of the work as being very complete for the time in which it was made. Another piece he speaks of also, which he had seen in the early part of his time, which was a watch belonging to the same king Henry VIII. which went a week. But these pieces must have been subject to great irregularities, as time-keeepers, and the same remark may be applied to all the clocks and watches which had been constructed before the application of the pendulum to the one, and the balance-spring to the other. So that before these applications had been made, philosophers had adopted the use of the pendulum,* exclusively, as a correct method of measuring time. The famous Tycho Brahe is supposed to have made use of them; but Strumius saith, that Riccioli first made use of pendulums to measure time, and that Langrene, Wendeline, Mersenne, Kircher and many others followed the practice, although they were ignorant that he had recourse to it before them.

Although several different persons have laid claim to the excellent invention of applying the pendulum as the governing principle to clocks, yet Mr. Christian Huygens affirms that he first applied it to clock-work, and gives very cogent reasons for it; and that he put it first in practice in the year 1657, and in the following year published a delineation and description of it. Galilæo laid claim to the invention, but it is certain that he never brought it to any perfection, and the invention never flourished till Huygens sent it abroad. After M. Huygens had contrived these pendulum clocks, and had caused several to be made in Holland, a Dutch clock-maker, called Fromantil, came over into England, and made the first that ever was made here,

* It may not be amiss to remark here, that a bullet fixed to the end of a string, when applied to such purposes, is called a pendulum, and as the times of their vibrations are known to be as the squares of their lengths, of course various periods may be marked out by them.

about

about the year 1662. One of the first pieces that was made in England was given to Gresham College by the late eminent Seth, lord bishop of Salisbury, which was formed exactly according to M. Huygens's method, with a crown-wheel and the pendulum playing between cycloidal checks. This method was practised for many years, till the application of the long pendulum, and at the same time the mode of escapement was altered. The late Dr. Hook claims the credit of this last improvement, the addition of the long pendulum. Sir Christopher Wren first proposed the pendulum as a perpetual and universal measure, or standard, to which all length may be reduced, and by which they may be judged of in all ages and in all countries.

Pendulum Clock.—In order to give the reader a tolerably correct notion of the machine which is the object of his present inquiry, it may be necessary to explain to him, that the chief and most essential part of the whole composition is the pendulum. To a cursory observer the pendulum may appear (in more than the literal sense of the word) to be an appendage to a complicated machine, whereas the fact is, that the whole complicated machine is really no more than an appendage to the pendulum, and that every part of the machine is constructed with a view to its subserviency to this instrument. It is the pendulum which is the efficient measurer of time, and the wheels may be considered as the recorders only, of those divisions of time which the pendulum marks out; and the wheels, instead of contributing to the *regularity* of its vibrations, are well known to disturb it. The prime office of the wheels is (by repeated impulses given at certain little periods), to prevent the pendulum getting to a state of rest. But as this effect may be produced by one wheel only, all the others are added to supply the maintaining power (from the weight or spring) to a longer period, so that the machine may not require a frequent attention to re-wind it. However, the train is so constructed, as to accord to certain relative periods, as seconds, minutes, hours, days, weeks, months, &c. But all these, however multiplied, must still remain under the same control.

Clock-making.—Since clocks have become so common as to be considered as articles of household furniture, the art of making them has not been confined as at first, to one department of mechanics, but has gradually been divided into various branches, so distinct from one another, that the maker of one part is frequently unacquainted with the operations of the other. Since the time that clocks became an article of our manufactories requiring various tools and engines for facilitating their construction, the subdivision of the art into various departments was a natural consequence, which has been found to contribute to expedition, and consequently to cheapness. A finisher of a clock has now no need to cast or cut his wheels himself, much less to make his springs, &c.; however, that man is called a clock-maker, who finally adjusts and puts together the different parts of a clock when made.

The art of clock-making is so nearly allied to that of watch-making, that after the full description we have given of the tools and operations of the latter art, it will be unnecessary to enlarge upon clock-making. The tools are in general pretty much the same, except that they differ in size. The first operation in making a clock, (as well as a watch), is the callipering, or setting out the positions of the pivot-holes for the several wheels; this is done by drawing it out on paste-board, and transferring the points or centres so ascertained to the plates of the clock, by pricking them through; this sets them out in a rough way, and then one of the pivot-holes being drilled, the places for the others are accurately determined by the pitching tool, as described in watch-work. The great size and weight of a pair of clock plates, with their connecting pillars, render the use of the upright tool inadmissible; but to be certain that the arbors of the wheels shall be truly perpendicular to the plane of the clock plates, the two plates are pinned together at each end before the holes are drilled, and then both plates are pierced at once by the drill, as well for the pivot-holes as for the four pillars, which being turned in the turn bench with truly flat shoulders, ensures the perpendicularity of the work when they come to be inserted in their places, so that the arbors will cross the frame at right angles to the surfaces of the plates, which is an essential condition in putting together the wheel work, and requires the workman to drill in as perpendicular a direction as *possible*, otherwise the plane of the wheels would not be parallel to the surfaces of the plates, and consequently the communication of motion would be given in an oblique direction, which would produce injurious friction and unequal wear among the teeth of the watch.

The preparation of the wheels and pinions of clocks is exactly the same as for watches, the pinions being made out of steel pinion wire, drawn with the right number of leaves, which are left standing at the part where the pinion is intended to be, and the rest of the wire is filed and turned cylindrical, the wheels are then fitted on and tried, as described in watch-making. As the pallet or swing wheel makes many more revolutions than any other wheel in the clock, it is necessary that the metal of which it is made should not be very destructible; it will therefore be best to use a tempered steel wheel, or one of brass well hammered, which ought to be also divided and cut with *extraordinary care*, because any irregularity in the shape of the tooth, or distance between the teeth, would injure the escapement, and produce, besides, such irregularity in the motion of the seconds' hand of the clock, which is placed on this wheel's arbor, as would offend the eye. There is no part of the clock which requires greater nicety than the escapement, or part which limits the quantity and duration of the impulse given to the pendulum by the maintaining power, and which keeps up the due quantity of motion of the whole machine, that would otherwise be gradually diminished

diminished till it came to a state of rest. To construct the escapement the clock-maker must set out or draw the exact form of the wheel and pallets, so that they may act properly, on a smooth sheet of brass, as a plate of trial for the escape, (see *Fig.* 10, *Plate* CLOCK-WORK), which will admit of pivot-holes being drilled exactly as in the plates of the frame, for the centres of the pallet and pallet wheel arbors. A piece of good steel must then be forged nearly into the shape of the anchor compared with the plan on the frame or brass plate, but somewhat larger; after the arbor-hole is drilled in the anchor and enlarged to the proposed aperture, the requisite circles may be described, with extents borrowed from the brass calliper, by means of a pair of bullet compasses, and the slopes may be copied or retracted for the faces of the pallets, the excluded metal may be then filed away very nearly, and all the surfaces be smoothed, first with fine files, and then with oil-stone-dust and oil.* Hitherto we have considered the back pivot-hole of the pallets' arbor as being in the plate of the frame, but it becomes necessary to cut away that portion of the back plate where the pivot-hole falls, by reason of the crutch, or little rod of steel, which must be screwed to a collet attached behind the frame to the arbor, to form an L, which contrivanse impresses the force that the pallets receive from the maintaining power upon the pendulum; the bent end of the crutch is usually inserted into a slit made in the verge or rod of the pendulum, but when the bent part is divided and encloses the pendulum rod, it is denominated the fork; the crutch is most usually about one-sixth part of the whole length of the pendulum rod; but there seems to be no fixed rule laid down by which its length might be determined.

The exact placing of the cock, so that the arbor pivotted into it shall be perfectly at right angles to the surface of the plates, is of the greatest importance, and therefore ought to be placed, and its steady pins fixed, before the original pivot-hole, through which it must protrude, is cut away in the back plate, for in that case, the protruding end of the arbor, on which to slide the cock and fix its position, before the steady pins are applied and the screws fitted to their places. It is, however, the practice of some workmen, to adjust the escapement by moving the cock before the steady pins are inserted, and a very proper mode, within certain limits.

Before the crutch is screwed it should be hung on the verge of the pallets' arbor, after the pallets are balanced and suffered to find the place of rest, in order to find its own perpendicular direction, and then it should be fixed in that situation; for without this care, it will require to be bent so as to offend the eye, for the purpose of putting the clock into beat, or will require a slit in it across the centre, to admit of an eccentric adjustment, or some such contrivance. When all the adjustments of the escapement are thus made, the pallet-faces and the pivots must be hardened, and finally dressed by the usual successive operation ofpolishing.

Of the Pendulum.—In the various attempts to mark out the divisions of time, nothing seems to have answered the purpose so correctly as the vibrations of the pendulum; and since the application of the pendulum to clocks, (I mean of the second's, or royal pendulum), they have obtained so much credit, as time-keepers, as to become useful in matters of science.

The vibration of the pendulum has indeed been found sufficiently correct, in its principle, to afford the means of discovering that the chief error which appeared in its use (at first), arose, not from the imperfection of the principle itself, but from that of the matter of which the *rod* was composed.

The celebrated Huygens, at first attributed the inequalities which he remarked in the pendulum, to their being performed in an arc of a circle, and that consequently the longer vibrations must be slower than the shorter. And he demonstrated in a Treatise* which he published, " That the vibrations of a pendulum, moving

* *The method of constructing Mr. Graham's dead escapement, as executed by Mr. John Shelton*, (Plate CLOCK-WORK, Fig. 10.)

Draw a circle of the exact size of your swing-wheel, and let fall a perpendicular on the point A, or centre of the circle, as B A, then if your wheel be of 30 teeth, and your escapement of 9½ teeth, set off from the vertical point C, 57 deg. on either side, as at D and E, double of which is 114 deg. and is the exact portion of the circle taken up by 9½ teeth. From the centre of the circle A, draw radii through the points of 57 deg. as A F, A G, and on the points where they cut the circle at D E, erect perpendiculars meeting in the verticle line at B, which gives the centre of motion of the anchor, (see the figure). Having thus obtained your centre of motion, describe, from that point, the arc H I passing through the points of 57 deg. which will give the circular face of each pallet on which the tooth rests in the dead part of the escapement. In the last place, the inclined planes of the pallets must make an angle with the radii A F, A G, of about 45 deg. intersecting them at the obtuse angle of the pallets. The angle is marked (in the figure) on both sides the intersection, in order to shew that it may be taken on either side; or the angle may otherwise be obtained, by measuring off from these obtuse angles of the pallets, chords of about 83 deg. on the original circle, as at *a b* and *c d*, (in the figure).

In escaping these pallets, you file away from the inclined planes of the pallets, till the tooth which has escaped from one pallet falls a little within the circular face of the opposite pallet, taking care not to alter the angles in this operation.

The teeth of the swing-wheel should be cut somewhat deeper for dead beating pallets, and the straight face of the tooth (not the sloping part) should act upon the pallets, and the face of the teeth should not point to the centre of the wheel, but about one-tenth of an inch on one side of it, so that the face of the teeth may tend a little forward.—The same mode of construction of pallets may be applied, with small variation, to those of the recoiling kind, by not filing the external arc of the pallet at D, but continuing the plane from D to K, and making the dotted line at D the face of that opposite pallet.

Whatever number of teeth you please to make your escapement of, you may take, from an exact line of chords, that portion of your circle (or swing-wheel) which that number of teeth occupies, and halving this measure, set it off each side the perpendicular, as above directed; for instance, if your wheel has 30 teeth, the portion taken of the circle will be

	Deg.		Deg.
For 8½ teeth	102	set off on each side	51
9½ - -	114	- - - -	57
10½ - -	126	- - - -	63
11½ - -	138	- - - -	69

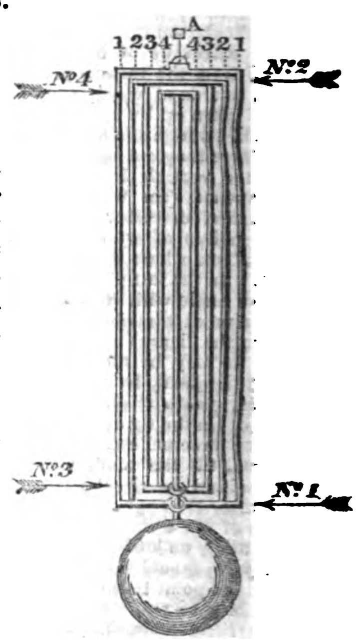
* Horologium Oscillatorium. 1658.

moving in a cycloid, must be performed in equal times, even though the vibrations are unequal." Pendulums were therefore made to vibrate in a cycloid, but still great inequalities remained, and after many ingenious experiments had been made, these inequalities were found to proceed from the change of temperature of the air, by its expanding or contracting the metal of which the pendulum-rod was formed. In consequence of this discovery several men of genius set about contriving means of obviating these irregularities, and three curious compound pendulums have been produced, and though these are very various in their constructions, yet they possess the same common principle, viz. that of making the expansion and contraction of one metal counteract that of another. The first in course appears to be the quick-silver pendulum, invented by the late very eminent philosophical mechanic, Mr. George Graham, and which is yet held in esteem.* In the same year (1726), Mr. John Harrison, of Barrow, in Lincolnshire, made a curious combination of rods, of brass and of steel, which by their different degrees of expansion and contraction, enabled him to make them counteract each other, so as to preserve the centre of oscillation always at the same distance from the line of suspension of his pendulum.† The next in course was Mr. Ellicot's compound-pendulum, with levers. This ingenious contrivance is found to operate to great exactness, and has a great advantage in the contrivance, by which the adjustment of the levers may be made, without tending to alter the time of its vibrations. Mr. Alexander Cummins has improved this instrument by his mode of executing it.‡ The skill and labour which are required to make one of these complicated pendulums, necessarily enhances the price so considerably, as to put them out of the reach of common purchasers. However, an excellent substitute has been found in the application of straight grained, well seasoned deal, for the rod of a pendulum, which has been proved by experiments to alter its length in so very small a degree, by heat and cold, as to render it a most eligible material for the above purpose. Respecting the pendulum, there are three things essentially necessary,—that the pendulum should be properly constructed, that its suspension should be most firm and steady, and that the impulses should be properly communicated to or from the wheels. Directions respecting each of these particulars shall be given at the end of this section.

Notwithstanding, it appears most obvious, that the correctness of a time-keeper must greatly depend on the equality of the vibrations of the pendulum; yet small attention has been paid till of late, to the manner of its suspension, the common mode being from a cock screwed to the upper part of the back plate, and totally unconnected with any firm fixture. Mr. Ludlam has remarked, that Mr. Harrison seems to be the first who in conversation and in print, insisted much on the importance of a very firm suspension of the pendulum; and he farther observes, that it appears, both from theory and practice, to be of more consequence than cycloidal checks, saddle-pieces, &c. all together. When it is possible, the pendulum should be suspended to a firm fixture to the wall itself.

Pendulum-bobs are generally formed with sharp edges, that they may pass through the air with less resistance; but this is not the best form, for when the bob is a pretty heavy one, it must necessarily increase its diameter considerably, and then its vibrations are more liable to be disturbed, by its edges not standing precisely in the plane of its vibrations, so as to subject it to be acted upon by the air, as an inclined plane, which evil its large surface will render it the more obnoxious to. Besides, the absolute quantity of resistance, or different states of the air, varies but very little, and as the resistance from the air increases with the arc described, it may operate as a check whenever the pendulum has a tendency, from other causes, to cross out beyond the usual limits.

It is not attempted to give the true proportions of the grid-iron-pendulum in the annexed Figure, as it is drawn much too broad (between the bars), in order to shew the bars the more distinctly, and and for this reason, the cross-braces are omitted.



Gridiron-Pendulum.—In this pendulum the bob is fixed to the single steel rod in the middle, and on each side this are four other rods, alternately of brass and steel, which are disposed so as to act in pairs, in order to support the weight of the bob, equally, on each side the centre. The rods of each pair are marked (in the figure) with the same numerical figure, and the transverse bars take the number of the dart which points to each. The expansion or contraction produced in brass and steel with the same change of temperature, are in the proportion of about three to two. The

* The quick-silver pendulum has been improved by Mr. Troughton, an eminent mathematical instrument-maker, who applies a glass tube with a bulb, (instead of the simple tube of Graham), by which means the variable surface of the mercury produces the necessary compensation to more advantage. See an account of this, Philosophical Trans. 1726, No. 392.

† See the Plate, with the explanation.

‡ See Elements of Watch and Clock-Work, by A. Cummins.

The pendulum being suspended at A, we will suppose for instance, that by the increment of heat, expansion takes place. Now it will appear from inspection of the figure, that in this instance, all the steel rods must extend downwards, and all the brass rods upwards, when the account will stand thus:

1st Pair steel rods, marked 1, 1, extend downwards, -	2
2d Pair steel rods, marked 3, 3, extend downwards, -	2
3d The single central rod extends downwards also, - -	2
Extension downwards	6

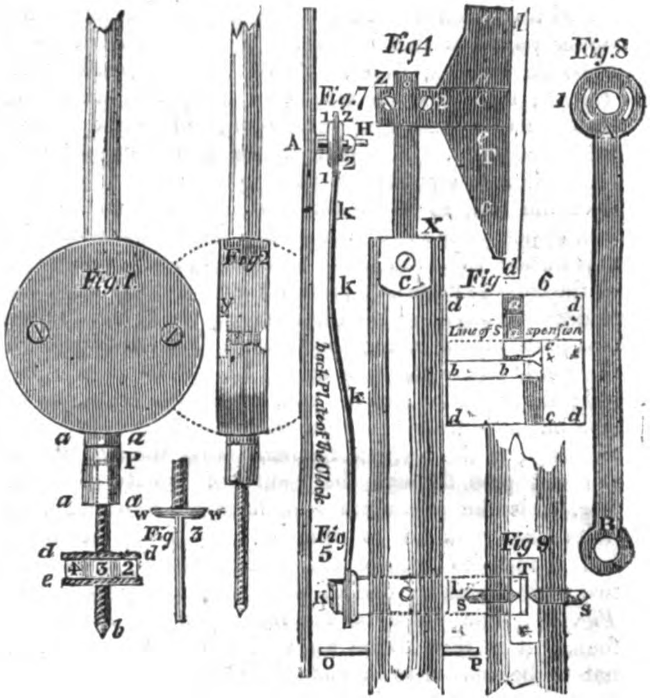
Now the proportional expansion of brass to steel being as three to two, of course the

1st Pair brass rods, marked 2, 2, extend upwards, - -	3
2d Pair brass rods, marked 4, 4, extend upwards, - -	3
	6

which exactly balances the above.

If this statement should not appear sufficiently plain, we will endeavour to explain the operation of each pair of rods distinctly; to do which, it will be necessary particularly to regard whence each particular pair of rods springs as from a root. The first pair of steel rods, being fixed to the upper rail (where the suspending spring is fixed), must of course stretch downward, and must carry down the under transverse piece equal to two; from this transverse piece (I mean No. 1), arises the first pair of brass bars, which of course will stretch upwards, equal to three, and will advance the rail, No. 2 (which is fixed on their extremities), in the excess, upwards of one. From this transverse bar (No. 2), spring the second pair of steel bars, marked 3, 3, which must stretch downwards (and like the first pair) equal to two. But as the rail whence they spring was carried up in the excess of one that must be deducted, and so the remaining excess downward is only equal to one. Now from this same piece (No. 3), arises the last pair of brass bars, which by their extending upwards equal to three, will advance the shortest transverse piece, seen at the top, equal to two only, as we must deduct the depression of their root equal to one. We now find the little transverse piece at the top (to which is fixed the central rod), to be advanced upwards in the excess of two. The last operation is that of the central rod, which sustains the bob, and this extending downwards equal to two, exactly counterbalances the remaining excess of two upwards, so that the centre of oscillation suffers no change. The effect of contraction of the several bars, by the operation of cold, produces the reverse of the above description, but this need not be gone over again.

Mr. Harrison having observed the effects of heat and cold on his thermometer curb, found that brass became sooner effected, by any change of temperature in the air, than steel, and therefore to counteract this superior susceptibility in brass, he advised, that, in constructing his gridiron-pendulums, the brass rods should be made somewhat stouter than the steel ones. In the above description, I have supposed the proportional change in brass and steel to be as three to two, to render the description free of fractions. But the real proportion is said to be as one hundred and thirteen to sixty-eight. In theory, Mr. Harrison's pendulum is considered to have the operation of five rods only, viz. two of brass and three of steel. Now to produce the effect, accurately, let the sum of the length of the two rods of brass be as sixty-eight, and the sum of the length of the three rods of steel be in the proportion of one hundred and thirteen, and by this inversion you obtain an equality of expansion in both metals.



A description of a pendulum with a wooden rod.—The rod of this pendulum should be made of a straight grained yellow deal, which you may procure from the lath-makers, it should be split down both ways; neither the sort which is white and spongy, nor that which is of a strong grain and full of turpentine. The rod is a cylinder of about $\frac{1}{4}$ of an inch diameter, and 42 inches long; it should be painted and gilt, and if varnished it would be less subject to changes from moist weather. The rod being first roughed out, a brass ferrule (*a*, *Fig.* 1, above), must be driven on its lower end, previously turned to receive it, the rod is then to be put into the lathe, the ferrule turned true, and a few other places in the rod may likewise be made round; the whole is afterwards to be planed straight, round and smooth, a hole is then to be drilled at the bottom of the rod, to receive the wire *b* along the axis. This wire should be steel, and the part which goes into the rod a little taper and rather larger than the hole in the end of the rod, the rest of the wire cylindrical, and the end conical; a

screw must be cut upon the cylindrical part with stocks; the wire must be forced into the hole at the bottom of the rod, and then cross-pinned through both ferrule and rod, as at P. The top of the rod, *Fig.* 4, is slit along the grain with a fine spring saw, to receive the spring at X, by which the pendulum is suspended; the two parts are to be drawn together by a screw, and made to pinch the spring; this screw passes through the quarter part of a brass ferrule and is tapped into the opposite quarter part; the head of the screw, with the first quarter, appears at *c*, *Fig.* 4. The spring is a piece of strong watch-spring which has never been coiled up, (such may be got at the spring-makers); the upper part has two cylindrical buttons rivetted to it opposite to each other, one of these appears at Z, *Fig.* 4; these bear the weight of the pendulum during the time of adjusting its suspension, before the screws are drawn tight. The ball of the pendulum is made of lead, and consists of two parts screwed together upon the rod, so as to pinch it. *Fig.* 2 is the ball as it appears edgewise, and shews the section down the axis of the rod, where the two parts join. The shape of the ball when the two parts are screwed together, is the middle frustum of a globe, as is seen by the figure. These two parts should be moulded from a neat turned pattern of wood, where the hole should be left to receive the rod; they may be cast so near their true form, as to give but little trouble in turning down in the lathe and finishing; if the pattern be made true, the axis of the rod will pass through the centre of gravity of both. *Fig.* 1, is the pendulum seen flatwise; two pieces of brass are soldered to the back part of the bow, and tapped to receive the screws which fasten the two parts together; one of these pieces appears at *y*, *Fig.* 2. The place of the ball upon the rod being found, it is then to be screwed fast to the rod, and not to be moved to regulate the clock. On the screw part of the wire, at the bottom of the pendulum-rod, is a cylinder of brass in two parts, the screw passing through the centre of both parts, see *Fig.* 1; the upper part, *d*, *d*, consists of a milled torus and a plain cylindrical part, both in one piece; the cylinder has numerical figures engraven on it, in the order they are represented in the plate, the lower part consists of a milled torus only, as at *e*, *e*. When the upper part is screwed to its proper place it must be held fast, and the lower part screwed against it, so as to pinch the screw-wire, and secure it against any accidental turning. Whenever there is occasion to move the upper part (in order to regulate), the under part must first be detached till the adjustment be made, and then screwed close again, as before. This part may be called the regulator, and will perform that office to a much greater correctness than where the whole ball of the pendulum is moved. It should be noted, that this regulator, as it appears in the plate, is represented at half size, and also the whole of *Fig.* 1, *Fig.* 2, and *Fig.* 6; all the rest are shewn at full size. Having thus described the pendulum-rod with its ball, we shall now describe the proper method of suspending it, which is by a projecting cock made of brass, and is composed of three distinct pieces, fixed together with rivets and screws. It is difficult to describe the exact form of it without giving many views of it, but the general principle may be easily explained. Strength and steadiness are particularly sought in its formation, and the side view, *Fig.* 4, will make it appear how those are attained in the vertical line, by the part marked *a*, *a*, above the line of suspension, and that marked *c*, *c*, below the line, as these serve as strong butments each way in that direction; but the part which serves as its butment in the horizontal line does not appear in the side view, but may be seen in the plan, No. 6 (which for want of room we were obliged to reduce in size); the form of the part from *b* to *b*, is the same as that seen in the side view from the dotted line *c* to *c*. The screw marked at Z, *Fig.* 4, appears sideways in the plan, and is marked there *x*; this screw goes through the two parts, which project forward to hang the pendulum upon. The right angled part, *d*, *d*, *b*, *b*, (*Fig.* 6,) is fixed to the flat brass plate by three rivets, as large as their thickness will admit, one at the angle near the lower *b*, and one at each extremity of the piece; the parts are put together by rivetting, that when separate they may be hammer-hardened. This cock is firmly fixed to a strong piece of wainscot which is placed against the back of the clock-case, and the whole firmly attached to the wall. The mode of suspension should be such, that none of the lateral motion of the pendulum, as it vibrates, can be communicated to the parts of the apparatus, nor should the whole, however firm, be liable to be disturbed by foreign causes. The two planes of the cock at Z, which are to receive the spring between them, should be filed flat when the plate T is taken off, and thus the spring may be pinched firm between them; so also should the cheeks of the slit at the upper end of the rod, so that the spring should not have the least play at either of its terminations, otherwise its force will be very unequal. In placing the cock, care should be taken that the place where the spring bends, (*Fig.* 4,) should be adjusted to the level of the verge or arbor of the pallets at A H.

When the pendulum is to be suspended upon the cock, take out the screw marked ⊕, *Fig.* 4, and release the screw at 2, and hang the pendulum-spring between the two planes at Z, *Fig.* 4, putting the cylindrical buttons which are rivetted at the top of the spring, into the hollow made to receive them at Z, then return the screw into its place, but do not tighten it; then tighten the screw *c* at the top of the pendulum-rod, and afterwards the two screws, H, 2, which will secure it in its place; and from its having hanged freely before these screws were tightened, the several parts will have been drawn into the true perpendicular line; the clock is afterwards put to it. We shall now explain the contrivance by which the pendulum receives its impulses from the wheel-work. A, *Fig.* 7. is the verge

verge or arbor, on which the pallets are fixed; 1, 1, is a round piece of brass rivetted to the collet; *k*, *k*, *k*, is the stem of the crutch, seen edgewise, and in *Fig*. 8 it appears flatwise. In the centre of the upper part is a round hole, A, made to fit the verge; and at 1, 2, are two circular slits. In *Fig*. 7, at 2, 2, is another round piece of brass, fitted rather loose on the verge; the screw at A, and another on the opposite side, go through the fixed plate marked 1, 1, and also through the curved slits in *Fig*. 8, marked 1, 2, and are tapped into the plate marked 2, 2, (*Fig*. 7,) so that the crutch has a considerable motion round the centre of the verge, and may be fixed in any position by these screws, one of which only can appear in this view, and is opposite to A, *Fig*. 7. At the other end of the stem of the crutch, (*Fig*. 8,) is a hole to receive the screw-shank of the steel piece seen edge-wise, *Fig*. 3, and when screwed up, appears at K, L, (*Fig*. 5.) The sides of this piece must be filed flat, and polished, or at least a fine grain given to it; its thickness should be about $\frac{1}{14}$ of an inch; the end of the flat part is seen at *Fig*. 9. The shoulder marked *w*, *w*, (at *Fig*. 3,) should be turned flat, and when the screwed shank is put through the hole B of the crutch, in order to fix it, a collet of brass should be interposed between the nut and the face of the crutch; this collet or brass plate should be turned hollow towards the crutch, and somewhat round towards the nut, which will make binging more effectual. The flat faces of the steel part must be set parallel to the line A B, (*Fig*. 8.). An oblong hole is pierced through the wooden rod, *Fig*. 9, in the direction of the axis of the rod; two fine steel screws *s*, *s*, are tapped through the sides of this hole. These screws pinch the flat part of the steel piece between them; the ends of the screws which bear against the plate are somewhat rounded off; the ends of these screws and the flat part they bear against must be made as hard as possible. The holes for the screws must be made at right angles to the flat sides of the faces of the steel piece, and must pass through the axis of the rod. These screws are $\frac{1}{10}$ of an inch in diameter, and have eighty threads in an inch. They must be forced in so as to cut their own threads in the wood, after which they must never be turned quite out. After having properly suspended your pendulum, and come to set up the clock, draw back the screws *s*, *s*, (*Fig*. 9,) so as to leave room for the flat of the steel part, T, to enter clearly between them. We are now come to set the clock into beat, in order to do which, release the screws at A, (*Fig*. 7,) and its opposite screw, (which is hidden in this view,) so as just to let the verge move stiff in the hole of the crutch. The frame containing the wheel-work must then be set into its place, carefully directing the flat of the crutch between the screws, which pass through the sides of the rod. After having screwed down the frame of the work to the rising board as usual, the crutch must be held fast whilst the pallets and verge are turned so as to bring the clock into beat. The screw at A (*Fig*. 7,), and its opposite must then be tightened, so as to set the pallets and verge fast to the crutch. Note, the back frame must be cut so as to get at the heads of these screws with a key, from the front of the clock. These screws have square heads, not slits, and are turned with a key, to prevent the thrusting forwards which is necessary when a turn-screw is used. The clock may be adjusted into beat to a curious niceness, by releasing one of the screws, *s*, *s*, (*Fig*. 9,) and screwing up the other; take care not to overturn these screws so as to strip the threads in the wood. The rule to be observed is this, you must always hear the flat, T, *Fig*. 9, strike against the screws, and if you do but hear it, they cannot be too close; these parts should be oiled. O, P, *Fig*. 5, is a piece of steel wire, which passes through the axis of the rod in order to catch it, by means of two slips of wood properly carved, and fastened to the rising board, so that this wire just sweeps clear of it in the vibrations of the pendulum. The more curious mechanic will easily perceive, that if the above work be carefully executed, according to the directions given, the impulses will be given in the axis of the pendulum-rod, and thence conveyed to the centre of gravity of the ball, circumstances absolutely necessary to produce a steady and regular motion of the pendulum.

A change of temperature equal to four degrees of Fahrenheit's thermometer, will produce an error in the going of a clock per day,

If with a steel rod, - -	1″
Brass, nearly - - - -	2
Glass, - - - - - - -	$0\frac{1}{2}$

By observations of transits of the sun over the meridian, made by Professor Bliss, he found that a clock of Dr. Bradley's, made by Mr. Graham, with a brass rod to the pendulum, gained in the coldest weather, of two winters, above 15″ per day, and in the hottest weather, of two summers, lost above 18″ per day, and in temperate weather went very near to equal time.—*Mr. Bliss's Letter to Mr. Short.*

Mr. Ellicott states the comparative expansion and contraction of the several different metals given below, to be as

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	Lead.
73	103	95	89	60	56	149

The length of the pendulum that swings seconds in the latitude of London, is $39\frac{1}{5}$ inches, or 39,2. Now to find the length of a pendulum that shall make any other given number of vibrations (in the same latitude) in a minute; say, as the square of the given number of vibrations is to the square of 60, so is $39\frac{1}{5}$ inches, (being the standard length) to the length, in inches, of the pendulum sought.

A pendulum that vibrates seconds at the equator must be $\frac{128}{1000}$ parts of an inch shorter than one which vibrates seconds at London, (or in that latitude;) and a pendulum that vibrates seconds at the poles must be $\frac{88}{1000}$ parts longer than one that swings seconds at London. The cause of this difference arises from the spheroidical difference of the earth, and the centrifugal

fugal force diminishing, as the diurnal motions become slower and slower, from the equator to the poles. A pendulum that vibrates seconds at the equator is 39 inches in length. And to vibrate seconds at the poles a pendulum must be the length of 39.226 inches.

A Table shewing how much a pendulum that swings seconds, at the equator, would gain every twenty-four hours in different latitudes; and how much a pendulum would need to be lengthened, in these latitudes, to make it swing seconds therein.

Latitude of the place. Deg.	Time gained in one day. Seconds.		Lengthening the pendulum to swing seconds. Inch.	Parts.
5	1	.7	0	.0016
10	6	.9	0	.0062
15	15	.3	0	.0138
20	26	.7	0	.0246
25	40	.8	0	.0369
30	57	.1	0	.0516
35	75	.1	0	.0679
40	94	.3	0	.0853
45	114	.1	0	.1033
50	134	.0	0	.1212
55	153	.2	0	.1386
60	171	.2	0	.1549
65	187	.5	0	.1696
70	201	.6	0	.1824
75	213	.0	0	.1927
80	221	.4	0	.2033
85	226	.5	0	.2050
90	228	.3	0	.2065

The opposite Table may be useful to such clock-makers who have clocks to construct for particular situations, such as turrets, &c.; or it may be consulted to advantage when they have a clock to alter, in order to accommodate it to a different purpose from the original one.

A Table shewing of what length a pendulum must be to make a given number of vibrations in a minute, in lat. 51° 30″.

Vibrations in a minute	Length of Pendulum. Feet.	Inches.	Vibrations in a minute	Length of Pendulum. Feet.	Inches.
10	116	8,608	95	1	3,597
15	52	2,048	100	1	2,068
20	29	4,154	105	1	0,776
25	18	8,377	110	0	11,641
30	13	0,512	120	0	9,782
35	9	6,998	125	0	9,015
40	7	4,038	130	0	8,335
44	6	0,759	135	0	7,728
45	5	9,561	136	0	7,615
50	4	8,344	137	0	7,510
55	3	10,465	138	0	7,396
60	3	3,200	139	0	7,201
65	2	9,340	140	0	7,187
70	2	4,747	141	0	7,085
75	2	1,042	142	0	6,985
80	1	10,009	143	0	6,886
85	1	7,490	144	0	6,793
90	1	5,390	145	0	6,699

Vibrations in a minute	Length of Pendulum. Feet.	Inches.	Vibrations in a minute	Length of Pendulum. Feet.	Inches.
146	0	6,608	164	0	5,238
147	0	6,518	165	0	5,211
148	0	6,431	166	0	5,112
149	0	6,345	167	0	5,051
150	0	6,260	168	0	4,991
151	0	6,175	169	0	4,932
152	0	6,096	170	0	4,847
153	0	6,017	171	0	4,817
154	0	5,939	172	0	4,761
155	0	5,863	173	0	4,707
156	0	5,788	174	0	4,652
157	0	5,715	175	0	4,599
158	0	5,643	176	0	4,547
159	0	5,572	177	0	4,496
160	0	5,502	178	0	4,445
161	0	5,434	179	0	4,390
162	0	5,367	180	0	4,347
163	0	5,301	300	0	1,565

The setting a clock into beat is effected in *common clocks* by bending the crutch one way or the other till the vibration on each side is equal. The trial of this is easily made, first marking on the clock-case, or other fixture, the exact point opposite which the pendulum-ball hangs, when perfectly free and at rest; then, moving it by hand slowly to one side until the tick or the escape of the wheel of the pallet is heard. Mark the point when this occurs, then move the ball to the other side of the centre, and also mark the opposite point of the escape, and if these two are equally distant from the centre or point of rest the clock is correctly in beat; but if it is not, the crutch of the verge must be bent, or, in more complete machines, an alteration made by screws, as directed in section pendulum, to one side or the other till this is effected. It is also an essential condition that the centre of suspension of the pendulum shall be exactly in the same vertical plane with the centre of the verge, for if the pendulum-spring happen not to coincide with a perpendicular line passing through the pivot hole of the pallets' arbor one half the arc of vibration will be greater than the other, even after the bending or eccentric adjustment of the crutch has brought the clock to beat. An error of this kind must be very obvious, and may be remedied by the eye.

The clock is now finished, and only requires to be adjusted to the proper rate so that it will keep true time. The adjustment is made by turning the nut at the bottom of the pendulum-rod, letting the bob down if the clock gains, or raising it up if it loses time, as is shewn by comparison with some other accurate clock, or else by the stars.

The ingenuity displayed by the Dutch in the construction of their wooden-clocks, has induced us to give a drawing of one of the best kind, and it is to be observed that this is a very tolerable kind of clock when made in brass; but even when framed in wood, with brass

brass wheels, as shewn in our drawing; it will keep time while its simplicity and cheapness render it worthy of attention. It is well adapted to a kitchen.

Fig. 1, *Plate* CLOCK-WORK, is an elevation of wheel-work of the going part of the clock, supposing the dial-plate removed, but the hands, *m* and *n*, remaining in their places. The circles of the dial-plate are represented by the dotted circles in the figure.

Fig. 2 is an elevation taken sideways, and shewing both going and striking movements at one view.

Fig. 3 is an elevation taken from behind, and exhibiting the wheel-work of the striking mechanism.

The frame of this clock consists of two flat boards AB united by four wooden bars, or pillars, at the angles, and also three upright pieces C D E, which contain and support the wheel-work.

F, *Fig.* 2, represents the dial-plate attached to the boards. A B and G represent a similar board, fastened in the same manner, to the boards A B behind the clock; this board has a hole through it, at the upper hand, by which the clock is suspended upon the pin or spike H, driven into the wall M; and the board G has two small legs or pillars L, projecting from the bottom, which have sharp points in their ends bearing against the wall. By this means the clock is firmly fixed and kept at such a distance from the wall as to admit the pendulum I K to vibrate freely between them.

The pendulum is simply a wooden rod I K, with a weight or ball attached to the lower end, and suspended at the upper end by means of a wire hook fixed into it. If this is taken from the point of suspension to a little below the centre of the ball, it measures 39,1$\frac{4}{10}$ inches, and, as before stated, every vibration will occupy one second of time. This is the measure of time for the clock, which has only to record the number of vibrations the pendulum has made, and, at every time, to give it a slight impulse sufficient to continue its motion, which must be done by a maintaining power, the action of which is transmitted to it by a train of wheel-work, as we shall describe.

The clock is provided with two distinct trains of wheel-work, one adapted to what is called the going part, because it is constantly in motion, and actuates the pendulum with a slight impulse at every vibration, at the same time carries round the hands to indicate the number of vibrations which the pendulum has performed. This mechanism, in the clock before us is, contained within the space between the uprights C D of the plane, except that some of the movements, called the *dial-work*, is contained between the upright C and the back of the dial F; this motion is particularly shewn in *Fig.* 1. The other train of wheel-work is for the purpose of striking the hour upon the bell N, which is mounted on the top of the clock. The striking mechanism is contained between the two uprights D E of the frame. The going part of the clock is actuated by a weight which is attached to a cord P, *Fig.* 1 and 2; this cord passes over a pulley Q, which has pins in the bottom of its grooves to catch the cord and prevent its slipping. The other end of the cord O, *Fig.* 1, has a light weight appending to it, which keeps the cord to a proper tension, and holds it upon these pins. The pulley Q is fixed upon a spindle which also carries the great wheel *a*; the latter is loosely fitted on its spindle, so that it slips round freely upon it, but to cause it to turn with it when required. The edge of the pulley is serrated or cut with sloping teeth like a ratchet, and a click is attached to one of the arms of the wheel, which, holding on the teeth, compels the wheel to turn round with it in the direction when the weight P is descending; but when the clock is to be wound up, which is done by pulling the end O of the cord, the pulley and spindle slip round without giving any motion to the great wheel, because its click slips over the sloping sides of the teeth of the ratchet cut on the edge of the pulley. The great wheel has seventy teeth, and actuates a pinion or lantern of seven leaves upon a second arbor, marked 28 in *Fig.* 2: it has on it a wheel *b* of seventy teeth, which turns a pinion of seven teeth, on the axis of which the swing or scape-wheel *c* is fastened: this has forty-five serrated teeth, as is shewn in *Fig.* 1. In these teeth the pallets act; they are fixed on a spindle *d e*, called the *verge*, which passes through the whole of the frame, and has a lever *f f* fixed to it, which is bent outwards at the end, and passes through a hole in the pendulum-rod I K. By this arrangement it is evident that, at every vibration of the pendulum, the verge and the pallet will accompany it in its motion. The manner in which the escapement takes place of one tooth of the wheel for every vibration, is explained by the separate view in *Fig.* 5, which represents the vertical swing-wheel marked *e* in *Figs.* 1 and 2; it has forty-five teeth. *c e f* represents the pallets, moveable in conjunction with the pendulum, on the centre or axis *d*. One tooth of the wheel, as shewn in the figure, rests on the inclined surface of the outer part of the pallet *c*, on which its disposition to slide tends to throw the point of the pallet further from the centre of the wheel, and, consequently, assists the vibration in that direction. While the pallet *c* moves outwards, and the wheel advances, the point of the pallet *f*, of course, approaches towards the centre in the opening between the two nearest teeth; and when the acting tooth of the wheel slips off or escapes from the pallet *c*, another tooth, on the opposite side, immediately falls on the exterior inclined face *f*; and, by a similar operation, tends to push that pallet from the centre. The returning vibration is thus assisted by the wheel, while the pallet *c* moves towards the centre, and receives the succeeding tooth of the wheel, after the escape from the point *f*. Thus may the alternation be conceived to go on without limit, each vibration of the pendulum letting down a tooth of the wheel, and, in the act of escaping, it receives a sufficient impulse.

We have now described the *going part* of the clock, except those wheels called the *dial-work*, which give motion to the hands. The first wheel, *a*, *Figs.* 1 and 2, which revolves once in two hours, is not placed in the

the centre of the dial-plate, but a little below, and has its strong arbor passing through the vertical partition-bar c of the interior frame-work, and receives a wheel g, of forty teeth, and also a pinion h, of ten leaves, which are attached and asserted on this arbor by friction. The wheel g, of forty, which we have seen, revolves in two hours, drives a pinion k, *Fig.* 2, with a long tube, called the *common pinion*, which is concealed in *Fig.* 1, behind the wheel i. On the tube of this pinion k, which has twenty teeth, and which, therefore, revolves in one hour, is placed the minute-hand n, the end of the tube being squared to admit the square aperture of the hand. The pinion h, of ten leaves, which also revolves in two hours, drives the wheel i, of sixty teeth, in twelve hours, the tube of which admits, on its circular part, the hour-hand m, which consequently revolves in twelve hours ($2 \times \frac{60}{10}$). This work is denominated the *dial-work*, being that which regulates the relative velocities of the two hands, as seen in *Fig.* 1.

The next portion that offers itself for description, is, the *'larum*, which has an immediate connexion with the dial-work, and has the time of its going off limited thereby. On the tube of the twelve-hours wheel i is placed loose, or, at least, only so tight as friction will fix it. The small plate o, pointed to by the tail formed within the hour-hand m, which small plate has twelve hours engraven on it, and a pin inserted into it behind, which comes in the way of the lever, *Fig.* 1, every twelve hours this pin is put into a certain situation with respect to the hour of twelve and the lever p; also, in order that the pin may catch the said lever at a certain hour, placed under the tail of the hour-hand at any time previously to the hour intended; the consequence is, that when the twelve-hour wheel i has revolved far enough to prevent the pin of the small 'larum dial, borne by it to the end of the lever p, this lever is elevated a little; its arbor has its pivots running in the interior frame-work of the going part, and a second lever r is fixed on the same common arbor; this is also, at the same time, elevated from the pin fixed in the edge of an escapement crown-wheel s, shewn detached in *Fig.* 4, at which instant the small weight of the 'larum pulls the pulley x on the back of the escapement-wheel of the 'larum, and gives it a rotatory motion as long as the weight continues to fall. The escapement-wheel s, here mentioned, has coarse teeth of the serrated kind, which, like the escapement of a watch, act with two pallets on the perpendicular arbor, and have their frequency regulated by the vibration of the balance, whereas in this there is no regulator, but the pallets go and come alternately as fast as the impelling weight can force them to move. On the top of the perpendicular arbor v of these pallets is fixed a hammer with two faces, within the bell N, as represented by dots, which moving backward and forward from one interior side of the bell to the other, with the force communicated to the pallets v, by the pallet-wheel s, make a reiterated noise, the intensity and continuance of which are sufficient to disturb the repose of a sound sleeper. When the weight has drawn up all the cord, it is only necessary to pull it up again, and the lever n acts as a detent with the pin fixed in the pallet-wheel, till the pin of the 'larum-dial o set to any given hour, shall again detach, when the same continued noise will be repeated. The pulley x, on which the cord of the 'larum acts is, as shewn in *Fig.* 4, connected with the escapement-wheel s, by a ratchet-wheel and click, which suffer the pulley to turn round independently of the wheel when the 'larum is wound up, in the same manner as the pulley of the going part.

The last portion of the clock is the striking portion, which also has a connexion with the dial-work. The wheel g, which, as before stated, revolves in the space of two hours, has two pins at the distance of a semicircle from each other behind the wheel, as is seen in *Fig.* 2; one or other of these two pins, at the end of each hour, seizes the end of a tail-piece (1) attached to the long horizontal arbor 2,3.; which reaches the whole depth of the two internal frames. This long arbor has another lever (4), *Fig.* 3, or detent, which reaches far enough to fall in way of a pin in the wheel (12), so as to arrest the motion of the striking f movement, when its quiescent position is parallel to the long arbor; and above it is another similar arbor turning by its pivots in the frame of the striking part. This upper arbor (5) has a wooden lever (6), *Fig.* 3, by which it may be raised by the contact of the detent (4) of the lower arbor 2,3. The end of the lever (6) is formed into two catches or detents, on one of these. The detents fall into a notch made in a projecting part of the axis (19), *Fig.* 3, of a wheel-mark (13), thence called the *detent-wheel*, which revolves once at every blow of the hammer. The second catch of the lever (6) is a wire-hook, marked (8), *Figs.* 2 and 3, which turns up and falls successively into (12) notches cut at unequal distances through the edge of the hoop, or ring, which is fixed fast to the wheel, marked (8), called the count-wheel, because its teeth and these notches count the stroke paces between the notches of the locking hoop, which are placed respectively at $\frac{1}{78}$, $\frac{2}{78}$, $\frac{3}{78}$, &c., of the circumference of the plate from each other. To explain this, it must be observed, that the wheel has seventy-eight teeth; the space between the notches in the hoop increase in arithmetical proportion; the space between the two first being one tooth, or $\frac{1}{78}$ of the wheel; the second space is equal to two teeth, and so on, till the twelve, which is twelve teeth, is extant.

The wheel (9) first actuated by the cord or chain passing round the third pulley fastened in it, has twelve pins fixed to it for raising the tail-piece (10) of the hammer. The arbor of the tail-piece (10) is seen in *Figs.* 2 and 3, marked 17; it has, at the opposite end, a lever (19), which operates on a short lever projecting from a vertical arbor (20), which has the hammer (16) fixed on the top of it, which is thrown towards the bell by a spring, marked 21, so that, as the great wheel turns, its pins seize the hammer-tail (10), and,

and, by depressing it, its arm (19) acts on the arbor (20), and draws the hammer (16) from the bell till the pin quits the tail (10), then the spring (21) throws the hammer against the bell.

The pin-wheel, or striking-wheel (9), has sixty teeth, and drives a pinion of ten leaves, marked 10, on the arbor of the detent-wheel (13), which has seventy teeth, driving a pinion on the remote end of the arbor of the warning-wheel (12) of fifty-six teeth, which wheel again turns the pinion (14) of seven leaves on the arbor of the fly, which is seen at 15. On that end of the arbor of the pin-wheel, which passes through the back part E of the frame-work, is inserted a pinion of twelve leaves, called the pinion of report, driving the counting-wheel (11) of seventy-eight teeth, which has been before-mentioned.

The action of the striking-part is this:—One of the pins in the two-hour wheel (9) first lifts the tail of the long lever, *Figs.* 1 and 2, and, with it, the detent (4), *Fig.* 3. The warning-wheel (7) is not yet at liberty, but it begins to revolve the instant that this detent has raised the wooden lever (6) of it, which raises with it both the catches or detents before described; then one of them leaves the notch made in the axis (10) of the detent wheel (13) and the other (8) leaves, the count-wheel, under the command of the suspended weight. The motion of the wheel, however, does not proceed far, because the detent (4) is raised into the way of the wheel (12), and the motion of the works is arrested. The noise of this temporary motion of the wheels is called the *warning;* and the wheel (12) the warning-wheel; presently the pin of the two-hour wheel *g*, drops from the end of the tail (1) of the arbor 2, 3, and thus during the temporary motion of the warning-wheel, the axis (10) of the detent wheel and also the locking attached to the count-wheel (11) had moved far enough, to take the notches from the claws of their respective detents, or catches, (6 and 8), the moment therefore that the detent (1) takes quiescent position, by the detent (1) slipping off the pin in the wheel *g*, the warning-wheel is again at liberty, as are also the detent-wheel and the count-wheel; the whole movement consequently now proceeds, and the pin-wheel raises the hammer-tail (10) as often as the pins meet with it, till the detent (8) meets with a notch to receive it into the locking-plate, at which moment all motion is at an end, because the detent (6) of the axis (10) falls also into its notch, and holds the whole movement in a quiescent state. At the end of another hour, the second pin of wheel *g* again detaches the detents, and renews the same process, which happens at the conclusion of every hour.

From this account of the movement of the striking-part, and of the other auxiliary parts of this mechanism, it is easy to apprehend the reason of the numbers of teeth, fixed upon in their different wheels and pinions, first, because there are twelve pins in the striking or pin-wheel, *g*, it is necessary that the pinion of report on the same protruding arbor should have twelve leaves, in order that every tooth in the count-wheel, one of which measures the first interval on the locking-plate, two of which measure the second, three the third, and so on, till the last space between the notches is measured by twelve teeth of this wheel. Again, as the pin-wheel (9) has sixty teeth and twelve pins, each pin is removed from the next $\frac{60}{12}=5$ teeth; if the detent-wheel (13) were necessarily obliged to have an exact revolution at every stroke of the hammer, the pinion on its arbor, driven by the pin-wheel (9), must necessarily have five leaves only; but when the teeth are not laid very deep into one another, the play will allow the hoop-wheel to have only one revolution in two strokes, which is the case before us, where the pinion has ten leaves. The pin-wheel, however, might very well have had ninety-six teeth, and the pinion in question eight leaves, and then there would have been an entire revolution of the hoop-wheel at each stroke.

We have seen that the count-wheel revolves once in twelve hours, and that the pin-wheel (9) revolves in $\frac{12}{78}$ of this time, or makes $6\frac{1}{2}$ turns in the twelve hours; but if the number of pins had been thirteen, the time of a revolution of these would have been $\frac{13}{78}$ of twelve hours, or once in two hours, which is the case of the great wheel *a* of the going-part, and the two movements would, in that case, have been more uniform, with respect to the calculations of continuance. It is but of little importance what the numbers of teeth be in the two remaining pinions and warning-wheel, as they only regulate the velocity of the fly, provided the teeth are numerous enough to act without much friction.

WEAVING.

WEAVING.

WEAVING is the art of making threads into cloth. This art is of very ancient origin. The fabulous story of Penelope's web; and, still more, the frequent allusions to this art in the sacred writings, tend to shew, that the constructing of cloth from threads, hair, &c., is a very ancient invention. It has, however, like other useful arts, undergone an infinite variety of improvements, both as to the materials of which cloth is made, the apparatus necessary in its construction, and the particular modes of operation by the artist.

Weaving, when reduced to its original principle, is nothing more than the insertion of the weft into the web, by forming sheds; but this principle has been so extensively applied in almost every country, and the knowledge of its various branches has been derived from such a variety of sources, that no one person could ever be practically employed in all its branches; and though every part bears a strong analogy to the rest, yet a minute knowledge of each of these parts, can only be acquired by experience and reflection.

The arts of spinning, throwing, and weaving silk, were brought into England about the middle of the fifteenth century, and were practised by a company of women in London, called silk-women. About A. D. 1480, men began to engage in the silk manufacture, and the art of silk-weaving, in England, soon arrived at very great perfection. The civil dissensions which followed this period, retarded the progress of this art; but afterwards, when the nation was at rest, the arts of peace, and, among others, that of weaving, made rapid advances in almost every part of the kingdom. It has been generally supposed, that silk-weaving, particularly that of figure-weaving, has never been brought to that perfection in England, to which it has attained in other countries.

The art of cotton-weaving, in its present improved state, has not been long known either in this or any other country. Wherever it originated, it is certain that most of our manufactures, in this respect, are unequalled in any part of the known world; and were it not for the many commercial restrictions, by which the present war is so unfortunately distinguished, there is every rational prospect that our cotton trade would be still further improved and extended.

The apparatus necessary in the art of cloth-weaving consists, chiefly, in the loom, shuttle, reed, and heddles, or harness, the form and use of which are here described.

When the weaver has received his warp from the warping-mill (for an account of which see COTTON-MANUFACTURE), his first care is to wind it upon the beam in a proper manner. When this has been done, and the cord made fast at both ends of the shaft, the knotting left by the warper is cut, and the warp stretched to its proper breadth. An instrument, called a ravel, is then to be used. Ravels are somewhat like reeds, and are also of different dimensions. One proper for the purpose being found, every half-gang is placed in an interval between two of the pins. The upper part, or cape, is then put on and secured, and the operation of winding the warp upon the beam commences. In broad works, two persons are employed to hold the ravel which serves to guide the warp, and to spread it regularly upon the beam; one or two to keep the chain, or chains, of the warp at a proper degree of tension, and one or more to turn the beam upon its centres. The warp being regularly wound upon the beam, the weaver prepares to take it through the heddles, and this operation is called drawing.

Before the operation of drawing commences, two rods are inserted into the lease formed by the upper-lease-pins on the warping-mill; the ends of these rods are tied together, the twine by which the lease was secured is cut away, and the warp stretched to its proper breadth. The beam is then suspended by cords behind the heddles and somewhat higher, the warp hanging down perpendicularly. The weaver then places himself in front of the heddles, and another person is placed behind. The former opens every heddle in succession, and it is the business of the latter to select each thread in its order, and deliver it to be drawn through the open heddle. The succession in which the threads are to be delivered is easily ascertained by the rods, as every thread crosses that next to it. The warp, after passing through the heddles, is next drawn through the reed by an instrument called a sley, or reed-hook, two or more threads being taken through every interval.

These operations being finished, the cords or mounting which move the heddles are applied; the reed is placed in the lay, or batten, and the warp is divided into small portions, which are tied to a shaft connected by cords to the cloth-beam.

When the weaver has finished these two operations of beaming and drawing, he proceeds to dress his warp.

warp. Dressing is justly esteemed of the first importance, in the art of weaving warps spun from flax or cotton; for it is impossible to produce work of a good quality, unless care be used in dressing the warp. The use of dressing is, to give yarn sufficient strength or tenacity, to enable it to bear the operation of weaving into cloth. It also, by laying smoothly all the ends of the fibres, which compose the raw material, from which the yarn is spun, tends both to diminish the friction during the process, and to render the cloth smooth and glossy, when finished. The substance in common use for dressing, is simply a mucilage of vegetable matter boiled to a consistency in water. Wheat flour, and sometimes potatoes, are the substances commonly employed. These answer sufficiently well in giving to the yarn both the smoothness and tenacity required; but the great objection to them is, that they are too easily and rapidly affected by the operation of the atmosphere. When dressed yarn is allowed to stand exposed to the air, for any considerable portion of time, before being woven into cloth, it always becomes hard, brittle, and comparatively inflexible. It is then tedious and troublesome to weave, and the cloth is rough, wiry, and uneven.

When the warp, previously dressed, has been wrought up, as far as can be done conveniently, the weaver is obliged to suspend the operation of weaving, and to prepare a fresh quantity of warp. It is necessary to stop, when the dressed warp has approached within two or three inches of the back leaf of the heddles, that room may be allowed to join the old dressing to the new. The first operation, as in wool and silk, is to clear the warp, with the comb, from the lease rod to the yarn roll, or beam. The proof that this operation has been properly executed is, by bringing back the rods, successively, from their working situation to the roll. When this has been done, the two rods nearest to the heddles, are drawn out of the warp to one side, and the lease rod only remains. The next duty of the weaver is, to examine the yarn about to be dressed, and carefully to take away every knot, lump, or other obstruction, which might impede the progress of the work, or injure the fabric of the cloth. In silk warps no further dressing is necessary; but in cotton warps the weaver proceeds to apply the substance used for dressing, which is rubbed gently, but completely, into the whole warp, by means of two brushes used in succession, one of which he holds in each hand. He then raises the lease-rod, which in cotton-weaving is a middle rod, on one edge, to divide the warp, and sets the air in motion by moving a large fan, for the purpose of drying the warp which has been dressed. Fustian-weavers use a large red-hot iron for this purpose. It is proper, in this stage of the operation, to draw one of the dressing brushes lightly over the warp at intervals, in order to prevent any obstruction, which might arise by the threads, when agitated by the fan, cohering, or sticking to each other, whilst in a wet state. Whenever the warp is sufficiently dried, a very small quantity of grease is brushed over it, the lease-rod is again placed upon its flat side, and cautiously shifted forward to the heddles. The other rods are then put again into their respective sheds, and the process is finished.

The first operation of dressing the warp being finished, the weaver begins that of forming the cloth. The operations required are only three, and these are very simple: 1st. Opening the sheds in the warp, alternately, by pressing the treddles with his feet. 2d. Driving the shuttle through each shed, when opened. This is performed by the right hand, when the fly-shuttle is used, and by the right and left hand, alternately, in the common operation. 3d. Pulling forward the lay, or batten, to strike home the woof, and again pushing it back nearly to the heddles. This is done by the left hand with the fly, and by each hand, successively in the old way.

In describing operations so simple and uniform, it is neither easy nor necessary to go much into detail. By examining any piece of plain cloth, it will be found to be composed of two or more distinct sets of threads, or filaments, running in opposite directions perpendicularly to each other; those threads (or, as some weavers call them, yarns) in the direction of the cloth's length are called the warp, and extend entirely from one end of the piece of cloth to the other. The thread, or yarn, running across the cloth in an horizontal direction is called the woof, or weft. It is in fact one continued thread through the whole piece of cloth, being woven alternately over and under each yarn of the warp, until it arrives at the outside one. It then passes round the yarn, and returns back over and under each thread, as before; but in such a manner, that it now goes over each yarn which it passed under before; thus firmly knitting or weaving the whole together. The outside yarn of the warp, round which the woof is doubled, is called the selvage, and cannot be unravelled without breaking the woof. The breadth of the cloth determines the number of yarns the warp shall contain; and its quality limits their distances from each other, and determines the fineness or set of the reed.

Stripes are formed upon cloth, either by the warp or by the woof. When the former of these ways is practised, the variation of the process is chiefly the business of the warper: in the latter case it is that of the weaver. By unravelling any shred of striped cloth, it may easily be discovered, whether the stripes have been produced by the operations of the warper or those of the weaver.

Checks are produced by the combined operations of the warper and the weaver.

Tweeled cloths are so various in their textures, and at the same time so complicated in their formation, that it is impossible to convey an adequate idea of the mode of constructing them, without the aid of several engraved figures. In examining any piece of plain cloth, it will be observed, that all the threads in

in the warp and woof cross each other, and are tacked alternately. This is not the case in tweeled cloths; for in this instance only the third, fourth, fifth, sixth, &c., threads, cross each other to form a texture. Tweeled cloths have been fabricated of various descriptions. In the coarsest kinds every third thread is crossed: in finer fabrics, they cross each other at intervals of four, five, six, seven, or eight threads, and in some very fine tweeled silks the crossing does not take place until the sixteenth interval.

Tweeling is produced by multiplying and varying the number of leases in the harness; by the use of a back harness, or double harness; by increasing the number of threads in each split of the reed; by an endless variety of modes in drawing the yarns through the harness; and by increasing the number of treddles, and changing the manner of treading them. When the number of treddles requisite to raise all the variety of sheds necessary to produce very extensive patterns would be more than one man could manage, recourse is had to a mode of mounting, or preparing the loom, by the application of cords, &c., to the harness; and a second person is necessary to raise the sheds required, by pulling the strings attached to the respective leases of the back harness, which are sunk to their first position by means of leaden weights underneath. This is the most comprehensive apparatus used by weavers for fanciful patterns of great extent, and it is called the draw-loom. In weaving very fine silk tweels, such as those of sixteen leases, the number of threads drawn through each interval of the reed is so great, that, if woven with a single reed, they would obstruct each other in rising and sinking, and the shed would not be sufficiently open to allow the shuttle a free passage. To avoid this inconvenience, other reeds are placed behind that which strikes up the weft; and the warp threads are so disposed, that those which pass through the same interval in the first reed are divided in passing through the second, and again in passing through the third. By these means the obstruction, if not entirely removed, is greatly lessened.

In the weaving of plain thick woollen cloths, to prevent obstructions of this kind, arising from the closeness of the set, and roughness of the threads, only one-fourth of the warp is sunk and raised by one treddle, and a second is pressed down to complete the shed, between the times when every shot of weft is thrown across.

Double cloth is composed of two webs, each of which consists of a separate warp and separate weft; but the two are interwoven at intervals. The junction of the two webs is formed by passing each of them occasionally through the other, so that each particular part of both is sometimes above and sometimes below. This species of weaving is almost exclusively confined to the manufacture of carpets in this country. The material employed is dyed woollen, and, as almost all carpets are decorated with fanciful ornaments, the colours of the two webs are different, and they are made to pass through each other at such intervals as will form the patterns required. Hence it arises, that the patterns of each side of the carpet are the same, but the colours are reversed. Carpets are usually woven in the draw-loom.

Gauze differs in its formation from other cloths, by having the threads of the warp crossed over each other, instead of lying parallel. They are turned to the right and left alternately; and each shot of weft preserves the twine which it has received. This effect is caused by a singular mode of producing the sheds, which cannot easily be described without the aid of drawings. Cross, or net-weaving, is a separate branch of the art, and requires a loom particularly constructed for the purpose. Spots, brocades, and lappets, are produced by a combination of the arts of plain, tweeled, and gauze-weaving; and, as in every other branch of the art, are produced in all their varieties by different ways of forming the sheds, by the application of heddles, and their connexions with the treddles which move them. Indeed, the whole knowledge of the art consists in this part of the apparatus of a loom.

Stockings are woven with a loom, which like other looms consists of treedles: of a bobbing of twisted silk, &c. fixed on a bobbin-wire, which it turns with ease to feed the engine: of a wheel, by the motion of which the jacks are drawn together upon *needles*; and of a needle on which the stockings are made. The loom is a very complicated piece of machinery, but by it, in its present improved state, stockings of all sorts can be made with great expedition. Some years since, a patent was taken out by Mr. George Holland, for a method of making stockings and other articles of wearing apparel adapted to give peculiar warmth to invalids, which may be thus described:—The work is to be begun in the common way of manufacturing hosiery, and having worked one or more course, or courses, in the common way, the workman is to add a coating in the following way: draw the frame over the arch, and then hang wool or jersey, raw or unspun, upon the beards of the needles, and slide the same off their beards upon their stems, till it comes exactly under the nibs of the sinkers; then sink the jacks and sinkers, and bring forward the frame till the wool or jersey is drawn under the beards of the needles, and having done this, draw the frame over the arch, and place a thread of spun materials upon the needles, under the nibs of the sinkers, and proceed in finishing the course in the usual way of manufacturing hosiery with spun materials. Any thing manufactured in this way, has on one side the appearance of common hosiery, and on the other side the appearance of raw wool. The raw or unspun materials may be worked in with every course, or with the second, third, fourth, &c. course, according to the warmth or thickness required.

Other methods are described in the specification, and

and it is added that hosiery may be cotted by any of these methods, not only with wool and jersey, but also with silk, cotton, flax, hemp, hair, or other things of a similar nature, raw or unspun, but the method which we have described, is reckoned by the patentee the very best. The method of making false or downy calves in stockings, is by working raw or unspun wool, or jersey, or any other raw or unspun materials into the calves of stockings, in the way already described.

Carpet-weaving.—Carpet is a sort of stuff wrought with the needle or on a loom, which is part of the furniture of a house, and commonly spread over tables, or laid upon the floor. Persian and Turkey carpets are most esteemed; though at Paris there is a manufactory after the manner of Persia, where they make them little inferior, not to say finer, than the true Persian carpets. They are velvety, and perfectly imitate the carpets which come from the Levant. There are also carpets of Germany, some of which are made of woollen stuffs, as serges, &c., and called square carpets; others are made of wool also, but wrought with the needle, and pretty often embellished with silk; and lastly, there are carpets made of dogs' hair. We have likewise carpets made in England, which are used either as floor-carpets, or to make chairs and other household furniture.

In weaving carpets the design or pattern is traced in its proper colours on cartoons, tied before the workman, who looks at them every moment, because every stitch is marked upon them, as it is to be in his work. By this means he always knows what colours and shades he is to use, and how many stitches of the same colour. In this he is assisted by squares, into which the whole design is divided; each square is subdivided into ten vertical lines, corresponding with the parcels of ten threads of the warp; and besides, each square is ruled with ten horizontal lines, crossing the vertical lines at right angles. The workman, having placed his spindles of thread near him, begins to work on the first horizontal line of one of the squares.

The lines marked on the cartoon are not traced on the warp, because an iron wire, which is longer than the width of a parcel of ten threads, supplies the place of a cross-line. This wire is managed by a crook at one end, at the workman's right hand; towards the other end it is flatted into a sort of knife, with a back and edge, and grows wider to the point. The weaver fixes his iron wire horizontally on the warp, by twisting some turns of a suitable thread of the woof round it, which he passes forward and backward, behind a fore thread of the warp, and then behind the opposite thread, drawing them in their turn by their leashes. Afterwards he brings the woof-thread round the wire, in order to begin again to thrust it into the warp. He continues in this manner to cover the iron rod or wire, and to fill up a line to the tenth thread of the warp. He is at liberty either to stop here or to go on with the same cross-line in the next division, according as he passes the thread of the woof round the iron wire, and into the warp, the threads of which he causes to cross one another at every instant: when he comes to the end of the line, he takes care to strike in, or close again all the stitches with an iron reed, the teeth of which freely enter between the empty threads and the warp, and which is heavy enough to strike in the woof he has used. This row of stitches is again closed and levelled, and in the same manner the weaver proceeds; then with his left hand he lays a strong pair of shears along the finished line, cuts off the loose hairs, and thus forms a row of tufts perfectly even, which, together with those before and after it, form the shag. Thus the workman follows stitch for stitch, and colour for colour, the plan of his pattern, which he is attempting to imitate; and he paints magnificently, without having the least notion of painting or drawing.

Tapestry-weaving.—Tapestry-work is distinguished by the workmen into two kinds, viz. that of high, and that of low warp; though the difference is rather in the manner of working than in the work itself, which is in effect the same in both, only the looms, and consequently the warps, are differently situated; those of the low warp being placed flat and parallel to the horizon, and those, on the contrary, of the high warp, erected perpendicularly. The English anciently excelled all the world in the tapestry of the high warp; of which the following is a description.

The loom, whereon it is wrought, is placed perpendicularly. It consists of four principal pieces; two long planks or cheeks of wood, and two thick rollers or beams. The planks are set upright, and the beams across them, one at the top, and the other at the bottom, or about a foot distance from the ground. They have each their trunnions, by which they are suspended on the planks, and are turned with bars. In each roller is a groove from one end to the other, capable of containing a round piece of wood, fastened therein with hooks. The use of it is to tie the ends of the warp. The warp, which is a kind of worsted, or twisted woollen thread, is wound on the upper roller; and the work, as fast as woven, is wound on the lower. Withinside the planks, which are seven or eight feet high, fourteen or fifteen inches broad, and three or four thick, are holes pierced from top to bottom, in which are put thick pieces of iron, with hooks at one end, serving to sustain the coat-stave: these pieces of iron have also holes pierced, by putting a pin, in which the stave is drawn nearer or set further off; and thus the coats or threads are stretched or loosened at pleasure. The coat-stave is about three inches diameter, and runs all the length of the loom; on this are fixed the coats or threads, which make the treads of the warp cross each other. It has much the same effect here, as the spring-stave and treddles have in the common looms. The coats are little threads fastened to each thread of the warp with a kind

kind of sliding knot, which forms a sort of mesh or ring. They serve to keep the warp open for the passage of broaches wound with silks, woollens, or other matters used in the piece of tapestry. In the last place, there are a number of little sticks of different lengths, but all about an inch in diameter, which the workman keeps by him in baskets, to serve to make the threads of the warp cross each other, by passing them across; and, that the threads thus crossed may retain their proper situation, a pack-thread is run among the threads, above the stick.

The loom being thus formed, and mounted with its warp, the first thing the workman does, is to draw on the threds of this warp, the principal lines and strokes of the design to be represented on the piece of tapestry; which is done by applying cartoons, made from the painting he intends to copy, to the side that is to be the wrong side of the piece, and then, with a black-lead pencil, following and tracing out the contours thereof on the thread of the right side, so that the strokes appear equally both before and behind.

As for the original design the work is to be finished by, it is hung up behind the workmen, and wound on a long staff, from which a piece is unrolled from time to time as the work proceeds.

Besides the loom, &c. here described, there are three other principal instruments required for working the silk or the wool of the woof within the threads of the warp; these are a broach, a reed, and an iron needle.

The broach is made of a hard wood, seven or eight inches long, and two-thirds of an inch thick, ending in a point with a little handle. This serves as a shuttle; the silks, woollens, gold, or silver, to be used in the work, being wound on it.

The reed or comb is also of wood, eight or nine inches long, and an inch thick on the back, whence it grows less and less to the extremity of the teeth, which are more or less apart, according to the greater or less degree of fineness of the intended work. Lastly, the needle is made in form of the common needle, only larger and longer. Its use is to press close the wool and silk, when there is any line or colour that does not fit well.

All things being prepared for the work, and the workman ready to begin, he places himself on the wrong side of the piece, with his back towards the design; so that he works in a manner blindfold, seeing nothing of what he does, and being obliged to quit his post, and go to the other side of the loom, whenever he would view and examine the piece, to correct it with his pressing-needle. To put silk, &c. in the warp, he first turns and looks at the design; then, taking a broachful of the proper colour, he places it among the threads of the warp, which he brings across each other with his fingers, by means of the coats or threads fastened to the staff; this he repeats every time he is to change his colour. Having placed the silk or wool, he beats it with his reed or comb; and when he has thus wrought in several rows over each other, he goes to see the effects they have, in order to reform the contours with his needle, if there should be occasion. As the work advances, it is rolled upon the lower beam, and they unrol as much warp from the upper beam as suffices them to continue the piece, the like they do of the design behind them. When the pieces are wide, several workmen may be employed at once.

We have two things to add: the first is, that the high-warp tapestry goes on much more slowly than the low-warp, and takes up almost twice the time and trouble. The second is, that all the difference the eye can perceive between the two kinds, consists in this; that in the low-warp there is a red fillet, about one-twelfth of an inch broad, running on each side from top to bottom, which is wanting in the high-warp.

But, for the satisfaction of our readers, we shall here describe the principal parts of the loom for the manufacture of tapestry of the high warp, or that in a situation perpendicular to the horizon. The loom consists, 1. Of two strong upright posts fixed in the floor: these support, 2. Two rollers, of which the upper end holds the chain, the lower holds the tapestry, which is rolled upon it according as the work goes forward: the threads are fastened at their ends to a dweet, or thick rod, which is lodged in a groove made in each roller. 3. The two tantoes, one called the great tantoe, for turning the lower roller. 4. The pole of the leashes, which runs quite across the chain, takes up all the leashes, and brings them to the workman's hand. These leashes are little strings, tied by a slip-knot to each thread of the chain, to be raised up according as the chain sinks down: they serve to draw the particular thread which the weaver wants. He holds the thread separate from the rest, and passes a spindle of such a woof and colour as he thinks proper: then he lets the spindle hang down, and hinders the thread from running off by a slip-knot. After having taken one or two threads of the fore-part of the chain by another leash, he brings the threads of the opposite side to him. By this alternative work he constantly makes them cross one another, to take in and secure the woof. In order to distinguish the threads of both sides, he is assisted by the cross-rod, which is put between two rows of threads. 5. A long tract of dots formed by the ends of the leashes which take hold of the leashes of the chain by a slip-knot; and on the other hand encompasses the pole of the leashes. 6. The cross-rod. 7. A little chain, each loop of which contains four or five threads of the warp, and keeps them perpendicular. 8. An iron hook, to support the pole of the leashes. 9. The broacher-quill, to pass the threads of the woof, which is wound on it. 10. The comb, to strike in the work. 11. The end of the dweet let into the roller, in a groove.

When the chain is mounted, the draughts-man traces the principal out-lines of the picture, which is to be wrought with black chalk on the fore and back side of the

the chain. The weaver in the upright way having prepared a good stock of quills, filled with threads of all colours, goes to work, placed on the back part, as in the flat way, or in the manufacture of the low-warp. He has behind him his drawings, on which he frequently looks, that he may from time to time see how his work succeeds on the right or fore side, which the other cannot do.

WHEEL-WRIGHT.

This artisan's employment embraces the making of all sorts of wheels for the carriages which are employed in husbandry, as well as for those adapted to the purposes of pleasure. Road-waggons and other vehicles constructed for burden, are also the manufacture of the wheel-wright. In London this business is divided into two distinct branches of work; one of which being confined to the purpose of manufacturing wheels for carriages of pleasure, is an appendage to coach-making; the other to the making of the bodies, wheels, &c. of the different kind of machines required for the transport of the various commodities for the purposes of trade, or the comfort and convenience of the people. It will appear by a very superficial examination, that such a business is of very great consideration, inasmuch as it contributes largely to the facilitating of our first necessities, by supplying the means of ready transit for articles of all descriptions, as well as in offering a similar comfort of quick communication for ourselves; and it is pleasing to reflect, that amidst all the various improvements in arts and manufactures, that this of wheel carriages has been by no means neglected. Our artisans in this line stand pre-eminent, our carriages are manufactured on better principles, as well as more neat in their execution, than are to be found in any other country.

It is intended here to describe first, the manufacture of a wheel as adapted to carriages of pleasure, and also to those of burden, pointing out at the same time the various improvements which have been made by the manufacturer for the different purposes of lightness and strength, as well as those which have been secured by a patent.

A wheel consists of three parts, viz. the nave or stock, which is its centre; the spokes which are radii from it, and the ring, which is the outside or periphery of the wheel. When a wheel is to be made, the workman ascertains its exact diameter, to which he adapts moulds of the length of the several fillies necessary to form its outside ring, or periphery. If it be a wheel for a carriage, he selects such fillies as are of small size to form it, these he chops away with his axe till they approach nearly to the form he wants them, and to the sweep of the moulds. The fillies are generally left in their length equal to admit of two of the radii or spokes being framed into each, and as much longer as to reach to the centre on each side between the two adjoining spokes. Twelve spokes are commonly assigned to the larger wheels of carriages, and ten to the smaller ones. The working and finishing of the several fillies to form the periphery of a wheel, consists, after it has been roughly chopped to the pattern, in forming its inside edge somewhat rounding, and getting its outside edge perfectly circular, and to form such an acute angle, as that when the wheel is adapted to the axle-tree, it shall stand square and solid under the body of the carriage. This is required from the circumstance that all wheels are made to a conical or *dish-shape*, as it is technically called, which is done partly for the purpose of keeping the dirt which collects upon their outer edge from splashing the body of the carriage. This dishing of a wheel, which is almost peculiar to this country, has given rise to considerable discussion. That it is by no means calculated to lessen friction, which ought to be the first consideration, is very obvious, and particularly if it be considered, that as being the frustum of a cone, it must be constantly operating against the line of draft of the power employed to give it motion. Hence its tendency is to impede rather than promote the effect of the impulse. Nevertheless, all our wheels are dished, and such is the power of habit, that to decrease the friction, the wheel-wrights, frequently in our largest road-waggons, increase the acuteness of their conical wheels, fancying, perhaps, that all they have to overcome lays in the breadth of the surface which they oppose to the road, which this kind of form, say they, "makes very little." Our wheels to road machines, perhaps, are the only things that have been neglected, in as far as giving to them those forms best calculated for their various purposes.

This is a subject requiring the attention of both the mechanician and mathematician, and for their attention to which, the public convenience would be much indebted. Principles must be laid down, and in such

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a plain and obvious manner, as to fix attention by their simplicity. By a scientific pursuit of this subject, it is probable that one-half the animal power now required for our road machines might be dispensed with, the roads improved, and science directed to its true end, viz. to the purposes of public utility. This digression arose only from the circumstance of our desire to promote the public convenience. The fillies, when accurately shaped, are cut to their several lengths, so as to make up the complete circle, or outside ring of the wheel, every one of their meeting joints being so formed as to approach exactly together close and firm. After the ring is thus worked and prepared, it is placed round, and the meeting joints corrected by planing, or saw-curfing, as it is called, till they become in a state capable of uniting very close when fixed to the spokes. Every joint is then perforated to about five or six inches deep by an auger, and a dowel of oaken wood is driven into the perforations; these are intended to keep the joints from springing, or getting out of place when the wheel is about to be put together. The fillies of wheels are commonly made of beechen wood, viz. from small trees, or the arms and branches of large ones; they are sawn into lengths of about three feet each, and rended by the pith of the piece, they are then chopped to a somewhat circular shape; the largest size being taken for waggon or cart-wheels, and the smaller for those to carriages. They are sold by a dealer, known as the filly and spoke merchant, commonly by the hundred of *five* score, and they vary as their size from 60*s*. to 200*s*. per hundred. The supply to London is generally from Yorkshire, but considerable quantities are gotten in Buckingham and Oxfordshire; but those from Yorkshire are most preferred by the coach wheel-wrights. The spokes of wheels are made from oak, rended from the small trees into pieces of from two to three feet in length, and to about three inches square; sometimes for the smaller description of wheels, they are rended to a quadrant form: they are vended by the hundred as the fillies are, and vary in their price as their size from 30*s*. to 60*s*. per hundred.

The manufacture of the spokes consists in chopping them first to their shape, and then smoothing them up with spoke-shaves to the form they are required; when this is done, they are all gauged to an exact length, and their shoulders are made, and the tenons left to enter the stock and fillies. The tenon intended to be framed into the stock or nave is generally left square, whereas that which enters the filly is round. The tenons at both ends are left somewhat larger at their shoulder than at their other ends, for the purpose of giving them greater tightness when fixed in their intended mortises. The tenon in the stock depends wholly for its firmness to the tightness of its framing; whereas that which enters the filly is secured by being wedged in its mortise on its outside edge. The strength of a wheel depends greatly on the attention paid to the arrangement and framing of the spokes; in common wheels they are framed regularly and equally all round the thickest part of the nave, the tenons of the spokes being so bevilled as to stand with reference to the horizontal position of the nave about three inches out of the perpendicular; this is done to produce what is called the dishing of the wheel. But for wheels of strength, and for instance the wheels to our mail-coaches, the spokes are framed somewhat differently into the nave, which is made also rather larger than is usual for common coach-wheels. The framing of the spokes in these wheels consists in getting every other one perpendicular to the nave. Hence the mortises to receive them in it are not made in a parallel line round it, but stand, as it were, in two different parallels, one without the other, by which means greater solidity is given to the nave, and an immense addition of strength to the whole wheel. This will appear rather more obvious, if it be considered that by this plan, supposing ten spokes to form the levers, five will be perpendicular to the weight of the body to be put in motion, and the other five inclining from it to produce the dish-shape; the wheels are found to resist their work considerably longer than any other at present employed to our lighter kind of wheel-carriages. This is a sufficient proof of their utility.

The stock, or nave, of a wheel is commonly formed of elm-wood. These are cut and sold by the hundred, as are the fillies and spokes, and vary also, *as their sizes*, from £5. to £7. per hundred. To produce their sound conical form, they are turned in a lathe, and many small projections and mouldings are left to give to them greater neatness when painted and finished. After the nave is turned, it is put into the hands of the wheel-wright, who divides and marks the places where he intends to form the mortises to receive the spokes; as he makes them, he tries the tenant of the spoke to each several mortise, and puts a private mark on the spoke he finds best adapted to fit into it. When these are all made and fitted, he begins to put the whole wheel together, fitting all the spokes to the nave first, and then adjusting and adding the fillies. When the wheel has arrived in this state it is put by to season; this consists in nothing more than placing it in a place exposed to a current of air, or, as at some manufactories, putting it into a kiln. A few hours is sufficient in it, when heated to about 140° of Fahrenheit, whereas a week or two will be necessary if it is to be seasoned by the natural means. The wheel, when properly seasoned, is knocked up together, and all its joints and parts are examined to see if they are in such a state as to come together firmly, and, if found to be so, they are all secured and fixed. This operation is begun by driving firmly in all the spokes to the nave, and then putting on the fillies or ring on the outside, which is also driven close down upon the shoulder of the other tenon of the spoke, which has been prepared to receive them. As these tenons pass quite through the fillies, they are secured by having wooden wedges driven into their centres, which

which has the effect of making them very tight and firm in the ring of the wheel. When this is done, the wheelwright cleans off, and finishes his work. This he does by using a spoke-shave to those parts which are uneven at the joints in the fillies, and when he has brought them fair and smooth, he rubs off the whole with dried fish-skin and glass-paper, till he gets the wood to a smooth ground adapted to receive the paint.

The last operation of the wheelwright in finishing a wheel, consists in putting on the iron-tire. The iron for making it is the flat bar-iron, in thickness and width, selected by the size of the ring of the wheel it is intended to cover. It is purchased of the iron merchant in bars of about twelve feet in length, by the hundred weight of 112lbs.; and varies in its price from sixteen shillings to one guinea per hundred. Such bars are cut into lengths equal to those of the fillies, they are then forged and hammered to the sweep of the ring of the wheel, having perforations made at every eight or ten inches apart, to admit the nails through, which are intended to secure them on the outside of the ring of the wheel. The iron-tire fillies are placed so as to cross each joint in the wooden fillies, and the nails, by passing quite through the latter, and being rivetted on the inside of it, tend exceedingly to strengthen the wooden ring of a wheel. The tire is also put on while *red hot* from the forge, and the nails are driven through it, and the wooden filly in a similar state, which promotes its firmness upon the wooden ring by burning down and compressing all bumps and other inequalities in the wood. Hence, when it is done, the wood and iron, by this kind of compression, becomes impressed one into the other, and produces great compactness, solidity, and strength to the periphery of the wheel.

The nails used for fastening the iron-tire on wheels are made on purpose for the work; they have square heads, forming a cube of about three-quarters of an inch each way. The driving part is about five or six inches in length, made quite flat and wedge-like, and they are larger or smaller in proportion to the size of the fillies and tire to be perforated and fixed by them. The coach wheelwrights now, in their better-most kind of wheels, have the iron-tire drawn into one complete ring, exactly adapted to surround the wooden one of the wheel. This has been found not so much to strengthen the wheel as to give it greater neatness. There was a patent obtained, about fifteen years since, for making the filly of the wheel in *one piece*, a method which had been long the practice in the North. The plan consisted in selecting beams of straight-grained ashen-wood, of the proposed size of the intended filly, and boiling it in a bath of water until the wood became reduced almost to a state of pulp, when it was bent on a cylinder of the diameter of the intended ring of the wheel. After which, it was shaped, mortised, and fitted to the spokes, as before described. Such kind of wheels are still continued to be made by a Mr. Greenstreet, at Lambeth, but the boiling the filly to give it its shape, greatly weakens it. Hence wheels, so made, are not in common use; they, however, are neater, and, of course, look much better than any wheel which can be made by the common method. The drawn iron-tire is always made use of for such wheels.

The boxing of a wheel, and adapting the axle-tree, is done usually by the coach or tire smith. The box of a wheel consists in a hollow conical tube of iron, furnished on its outside with two or three square projections, which have the effect of giving it a key when mortised through the nave of the wheel. The box is well polished on its inside, and the axle-tree is accurately formed to fit into it, with a sufficient play to admit of oil being introduced to modify the friction.

The external ends of axle-trees, which pass through the boxes, are generally formed into screws, to which are adapted nuts, of sufficient size to cover completely the external edges of the boxes of the wheels, which, with a linch-pin, that passes through both it and also the mortises in the axle-tree, completely secures the wheels to their work.

The patent boxes to the mail coaches are of a different construction, and owe their safety to four bolts, which pass completely through the nave of the wheel, having a square shoulder on the back of the nave, with screws and nuts on its front. The box to such a wheel is made, as are the other boxes above described, except being completely closed at its outer end, with a solid and broad cap of iron, of sufficient diameter to enclose completely the end of the nave. The axle-tree, too, is formed to fill the box, and press up close to this iron cap. There is also a large round iron flaunch made and welded to the base of the solid cone or axle, which works in the box of the nave. This cap has four perforations through which the iron bolts are put, and which also pass through the nave of the wheel with their screws presenting themselves through the iron cap at its outer end. When these bolts are all adapted and in their places, four nuts of about an inch and a quarter square, are screwed on to them, the shoulders of which are supplied by the iron cap, which secures the axle-tree in the box, and holds up the wheel more firmly to its work than by any other plan now adopted. By this method no dirt can penetrate to impede the motion or create friction, as the end of the cone of the working axle is completely enclosed, and when once the wheel is put on and properly oiled, it is found to go on in its work for a considerable time; for instance, the mail coaches go their longest journeys with oiling and rectifying in London only, where it is always done by a contractor specially retained for that purpose.

Collinge's patent box is of a similar construction, but being adapted to carriages of pleasure it was got up with greater neatness, being sometimes formed of solid silver on its outside, but mostly of brass or plated metal. Its principal object was to combine the properties of the above boxes, with some regard to elegance of shape, which has been accomplished. All the naves of wheels are capped with a ferrule of iron on their large or but-end, and the smaller naves at both their

their ends; this is done to prevent their splitting when wedging in the iron boxes, and it is also of use to keep the weather from cracking and dilapidating them. The manufacture of all wheels, either to carriages of pleasure or of burden, partakes of a similar mode of manufacture, varying the weight and size of the materials employed to their respective purposes.

In the provinces, the business of wheel-wright and carpenter is frequently combined; nor is this so much to be wondered at, if it be considered how large a proportion of their employ is embraced in making not only waggons and carts, but the machines for agricultural purposes, the most of which are manufactured at the wheel-wright's. In London it is different, as there trades are almost respectively pursued. The working tools of this tradesman do not differ greatly from those of a carpenter or joiner, but they are not so multiplied as is required by the latter. He is provided with two or three axes of different sizes, the largest of which is formed for cleaving and reducing his fillies and spokes to a rough form, approaching to what they are intended to be when more finished. The other axes are made with a broad but narrow chopper and short handle, and ground to an edge from their concave or inside only; their blade part is made convex on its outside, in order to its being applied to cut away the internal side of the fillies. The axes of the wheel-wright are kept uncommonly sharp, being whetted on a Turkey stone, as their plane irons and other tools are. They have also an adze similar to a carpenter's, with abundance of all kinds of gouges and chisels, which differ only from the common tools of that description by being furnished with longer handles, and made somewhat stronger. The handle is required to be longer, as the wheel-wright works on the floor at his work, and the additional length of his tool is for the purpose of enabling him to reach his labour more conveniently. His other tools consist of a numerous collection of augers of different sizes, varying from one-fourth of an inch diameter, to two inches or more; these he requires to perforate the fillies of his wheels, as the mortices in them are always round; he has also a stock, with a collection of centre, dowelling, and pin-bits, as they are called. He has several different sized spoke-shaves, which are used to smooth and finish the different portions of his work. The flat-iron, as it is termed, is also a tool much used by the wheel-wright; it consists in a long and narrow strip of hardened iron, about an inch wide, turned up to receive a handle on each of its ends; with a tool of this description the spokes and other similar pieces of work are prepared.

Their planes consist of a jack, trying, and smoothing plane, precisely the same as are in use among carpenters, and called after the same designations. Some portions of their work are occasionally moulded, to effect which they have a plane formed to produce it, and which is made exactly corresponding to a moulding plane of a joiner or cabinet-maker. Their hammers are of various sizes, some being very small, and others in size equal to that of a sledge, and they differ only from the common instruments of this description by being invariably made with a claw at one of their ends. It has been before observed, that this tradesman's employ includes as well as the making of wheels, that of carts, waggons, and implements in agriculture; these, it must be obvious, will partake in their shape and make from local circumstances; hence it is found that in almost every country a different manner is adopted, although the mechanical labour of the several parts is nearly every where the same. The machines employed in and about London are manufactured with a greater proportion of iron (from the wear and tear of traversing the pavement), than is found to be requisite in parts where roads of the common nature prevail. Wooden axle-trees are by no means uncommon in the country districts; but such axle-trees would not transport a slight load for an hour over the sudden jerks of a London pavement; hence machines of this description will always be formed to combine such advantages as are required from their local circumstances.

To describe a London waggon would be of no importance to the country manufacturer, where such a machine is unnecessary, and to the London manufacturer a country machine is not of the least utility. Our road-waggons certainly claim great attention, as combining all the properties of strength and lightness, but their wheels are badly formed. On this important point a paper has been presented to *the Board* of Agriculture, by Mr. Cumming, from which we shall here add some extracts: the same paper may be also further consulted by referring to the Repertory of Arts, vol. 13. page 257.

"The properties of all wheels, so far as regards this inquiry, depend upon their affinity to the cylinder or to the cone; and in order to shew the nature and tendency of each class, it is necessary briefly to state such properties as unavoidably arise from the form of these bodies. The cylinder having all its parts of equal diameter, will in rolling on its rim, have an equal velocity at every part of its circumference, and necessarily advance in a straight line. And as all the parts of the rim have an equal velocity, none can have a tendency to drag forward or retard the progress of the others; they all advance with one consent, without the rubbing of any part on the surface on which they roll. As there is no rubbing, there can be no friction, and consequently a cylinder perfectly round, hard, and smooth, forms the least possible resistance, however great its weight, or the pressure on its rim. It therefore follows, that all the power that is employed in drawing forward a cylindrical body in a straight line, on a compressible substance, is ultimately applied in compressing smooth and levelling the substance on which it rolls. The rolling of a cylindrical body therefore can have no tendency to alter the relative situation or position of the parts of materials on which they pass, nor any how to derange them, but by a progressive dead pressure to consolidate, level, and smooth them. If a cylinder be

cut

cut transversely into several lengths, each part will possess all the above properties, and if the rim of a carriage wheel be made exactly of the same shape it must necessarily have the same tendencies. When wheels, with cylindrical rims, are connected by an axis, the tendency of each being to advance in a direct line, they proceed in this connected state with the same harmony and unity of consent that exist in the parts of the same cylinder; but, as conical rims have been universally preferred for a series of years, it is natural to suppose that there were obvious reasons for such preference. The cone diminishing gradually from its base to its point, the velocity of every part of its circumference, in rolling on an even plane, will be diminished, as the diameter; and at the very point where there is no visible diameter, it will have no perceptible motion; but if the cone be made to advance in a straight line, the natural velocities of its several parts will not be as the spaces, therefore a rubbing and friction will take place at its circumference from the different velocities of its parts, which must render the draught heavier. In rolling on paved streets nothing can be conceived more calculated for their destruction than the conical rim of a broad wheel. It may be thought extraordinary that no good qualities should have been imputed to the conical shape of a wheel, although sanctioned by universal preference for so many years.—"But," says Mr. Cumming, "if any do belong to it except only the flat bearing of its whole breadth, I have not been so fortunate as to discover them." He says, also, "that conical wheels promote the destruction of the roads, increase the labour of the animals, and occasion an immense wearing of the tire of the wheels, by their constant dragging and grinding on the roads, none of which take place with cylindrical wheels."

WIRE-DRAWING.

The iron of which wire is made is smelted from the rich ores of Cumberland and Lancashire, by wood charcoal, and from the state of pig iron. It is refined into maleable iron, also, by the use of the same fuel, by which processes, and the entire use of wood, added to the excellent quality of the ore, the great ductility of wire iron is obtained.

When produced from the forge in bars, it is rolled into sizes suitable to the particular purpose for which it is intended, and being then softened or annealed by heat, is, when cold, scoured, by means of sand or gravel and water, in barrels formed for the purpose (and turned on their axis by machinery), till it is quite bright and clean, after which it is suffered to acquire a covering of rust by being splashed with water. When well dried it is drawn through plates of steel, in which are made tapering holes of smaller diameter than the size of the iron to be drawn, the rust giving its surface sufficient roughness to carry grease into the hole with it to prevent any scratches on its surface. Thus, by means of repeated annealings, scourings, rustings, dryings, and drawings, it is brought to the sizes required, which in iron amount to thirty-six, known in trade by the numbers 1, 2, 3, &c.

The first process of drawing is performed by very strong pincers moved to and fro by machinery, but these, as they move only a little way, leave marks of their bite at short distances along the wire, which is obviated by the use of wheels or blocks which revolve horizontally, so that one end of the wire being fastened in a vice fixed at its circumference, the whole is drawn constantly forward from beginning to end without any mark, and, at the same time, is formed into its rings or coils round the block during its revolution.

When the wire becomes too small to be scoured in barrels with gravel, without being tangled, it is obliged to be cleaned by means of diluted acid, when the process becomes again as before.

The very fine sizes are, at the best works, finished by hand labour, a small block being worked bright, and polished till completed.

The machinery employed is various at different works, but is chiefly remarkable for its strength, which is rendered necessary by the resistance that the iron affords to the tools.

The process with steel is similar to that for iron.

Brass and copper are prepared from the ingot, by rolling and slitting into strips or rods of the thickness and breadth necessary for the several sizes intended to be drawn; but the process of drawing is very similar to what has been described—See the article Gold-Beating, &c.

WOOL-COMBING.

This is a very ancient trade in our country, wool having been long reckoned one of its staple commodities. The raw material, as it is well known, is the hair or covering of the sheep, which, when washed, and combed, and spun, and woven, makes worsted, many kinds of stuff, and other articles adapted to the use, the comfort, and even the luxuries of life. While the wool remains in the state in which it is shorn from the sheep's back, it is called a fleece. Each fleece consists of wool of different qualities and degrees of fineness, which the wool-stapler, or the wholesale dealer in wool, sorts, and sells in packs, at different rates, to the wool-comber. For the London market, and for towns and villages in the neighbourhood of the metropolis, Bermondsey was formerly the resort of wool-staplers. The finest wool grows on and about the head of the sheep, and the coarsest about the tail. The shortest is on the head and some parts of the belly, the longest on the flanks.

The fineness and plenty of our wool is owing, in a great measure, to the short sweet grass in many of the pastures and downs; though the advantage of our sheep feeding on this grass all the year, without being obliged to be shut up under cover during the winter, or to secure them from wolves at other times, contributes not a little to it.

Wool is either shorn, while the sheep is living, or pulled off after it is dead. In the first case, it is called fleece-wool; the other sort, called skin-wool, if very short, is used much in the manufacture of hats. See Hat-Making.

Wool, in the state in which it is taken from the sheep, is always mixed with a great deal of dirt and foulness of different kinds, and, in particular, is strongly imbued with a natural strong-smelling grease. These impurities are got rid of by washing, fulling, and combing, by which the wool is rendered remarkably white, soft, clean, light, and springy under the hand. When boiled in water for several hours in a common vessel, wool is not in any way altered in weight or texture, nor does the water acquire any sensible impregnation.

The wool intended for the manufacture of stuffs is brought into a state adapted for the making of worsted by the wool-comber, who having cleared it from all impurities, and well washed it with soap and water, to drain it as much as possible from its water, he puts one end of a certain quantity on a fixed hook, and the other on a moveable hook, which he turns round with a handle, till all the moisture be completely forced out. It is then thrown lightly into a basket that is pretty open at the sides, as well as at the top. When he comes to use it with the comb, he scatters a few drops of oil on each layer of wool, as it is spread out, and then puts it closely together into a bin that is situated immediately under the bench on which he sits to work. At the back of the bench is another bin for the refuse wool, or *noyles* as it is called, that is, the part of the wool that is left on the comb after the sliver is drawn out.

The comb used in this trade consists of three rows of highly tempered and polished steel, fixed in a long handle of wood, and set parallel to one another. Each comber has two combs which he fills with wool and then works them together, till the wool on each is perfectly fine and fit to draw out in slivers. The best combs of this kind are manufactured at *Halifax*, in Yorkshire. In using these combs, the workman has a pot made of clay with holes in its side, in which he heats them to a certain temperature before they can be made to pass readily through the wool. Each comb-pot is made to hold eight combs, so that four men usually work in one compartment of the shop, round a single pot; of course there must be four separate benches, bins, &c. in it.

When the wool is sufficiently worked on the combs, the workman places one comb and then the other on a spike placed in the wall, or in a pillar attached to the wall, at a proper height for him to draw it out as he stands. The wool thus drawn out is called a sliver, and is from five to six or seven feet in length.

Wool-combing is preparatory to the manufacture of worsted yarn, and is the first process towards the making flannels, serges, stuffs, baize, &c. The manufactures connected with and depending upon this trade, are very important in foreign as well as domestic commerce. Hence wool-combers have in various instances been encouraged and protected by particular acts of parliament: thus by an act in the 35th of the present reign, all those who have served an apprenticeship to the trade of a wool-comber, or who are by law entitled to exercise the same, and also their wives or children, may set up and exercise such trade, or any other trade that they are equal to, in any town or place within the kingdom, without any molestation; nor shall such wool-combers, their wives and children, while they exercise such trades be removeable from such

place

place to their last place of settlement, till they actually become chargeable to the parish.

The wool being combed, it is next spun, which is now usually performed by machinery on a large scale, but when done by hand it is the employment of women and children: it is then to be wound on to little wooden articles called *spoles*, and these to the number of several hundred at a time, are put upon spindles placed round a mill, and worked into skeins of proper size for sale. They are now washed in soap and water, thoroughly dried, and if to remain undyed and white, they are blanched with the fumes of burning sulphur, and made up by the master comber or his principal man or men, when it is fit for sale. Such is the wool-combing for worsteds.

A pack of wool weighs 240lbs., and it is said, it will employ more than sixty persons a full week to manufacture it into cloths, viz. three men to sort, dry, mix, and make it ready for the comber or carder, where cards are used instead of combs; five to scribble it; thirty-five women and girls to card and spin it; eight to weave it; four to spole it; and eight to scour, mill, pack, and press it. When wool is to be made into stuffs, serges, &c., it will employ two hundred persons; and when made into stockings, it will afford work for a week to one hundred and eighty-four persons, viz. ten combers, one hundred and two spinners, winders, &c. and sixty stocking-weavers, besides doublers, throwers, and a dyer.

The price of wool, in this country, was in very early times, much higher in proportion to the wages of labour, than it is at present, because till the time of Edward III. it was always exported raw, the art of working it into cloth and dyeing it being imperfectly known here. The first steps taken to encourage the manufacture of woollen cloths was by Edward III., who procured some good workmen from the Netherlands by means of protection and liberal encouragement. The value of wool was considered as so great, that taxes were received in that commodity, reckoning by the number of sacks, and in proportion to the price of the necessaries of life, and the value of silver was at least three times dearer than it is now. The manufacturing of cloth being once introduced into the country, the policy of preventing the exportation of the raw material was soon evident, and the first act was in the reign of Henry IV.; by which the exportation of sheep, lambs, or rams is forbidden under heavy penalties. By a statute, in the 28th of the present reign, all former statutes respecting the exportation of wool and sheep are repealed, and numerous restrictions are consolidated in that statute; for an account of which we must refer to the act itself.

At the present period vast quantities of wool are imported from foreign countries: to give the reader an idea of the wool imported, we shall transcribe, from the Repertory of Arts, Vol. XII., an account of the wool purchased in foreign countries in the years 1802, 3, and 4, and employed in our manufactures of the finest woollen goods. In the statement, which is curious and very important, is included the probable expense to this country of the wool so purchased.

In the three years specified, there were imported, of Spanish wool, directly from Spain, 16,986,644 lbs.

Holland,	403,400
Portugal,	400,723
Gibraltar,	288,274
France,	252,222
Germany,	122,150
America,	10,567
Prussia,	3,357
Denmark,	381
Total	18,467,718 lbs.

Of this quantity, about 15,307,718 lbs. were imported in Spanish or neutral vessels, and the remaining 3,160,000 lbs. in English vessels.

Of the quantity imported in Spanish or neutral vessels, about 15,141,900 lbs. were sheeps' wool, and 165,778 lbs. lambs' wool. Of the sheeps' wool the proportions were, of the R, or first sort, about 12,000,000 lbs.; of the F, or second sort, about 2,000,000 lbs.; of the T, or third sort, about 1,127,000 lbs.; and of the K, or coarser sort, about 14,920 lbs.

The average prices given for these wools by the clothiers in England were nearly as follows:

			£.
R, sheeps' wool,	12,000,000	at 6*s.* *per* lb.	3,600,000
F, ditto,	2,000,000	at 5*s.*	500,000
T, ditto,	1,127,020	at 4*s.* 6*d.*	253,579
K, ditto,	14,920	at 3*s.*	2,238
Lambs' wool,	165,778	at 4*s.* 3*d.*	35,227
	15,307,718 lbs.		£4,391,044

These £4,391,044. were the sum paid by our clothiers for this wool. What the merchants' profit might be is not presumed to be determined; but if we allow 15 *per cent.* inclusive of interest, or £658,656. the remainder, or £3,733,288. will be the sum actually paid out of the kingdom for this part of the imported wool.

Besides these quantities, there were imported in British vessels about 3,160,000lbs. of Spanish wool; of which the respective proportions were, probably, nearly as follows:—

R, sheeps' wool,	2,477,182lbs.	at 6*s.*	£743,154
F, ditto,	412,864	at 5*s.*	103,216
T, ditto,	232,652	at 4*s.* 6*d.*	52,346
K, ditto,	3,079	at 3*s.*	461
Lambs' wool,	34,223	at 4*s.* 3*d.*	7,272
	3,160,000		£.906,449

From the gross amount of the latter sum, which is what is paid by the manufacturer, there must, in this case, be deducted not only the merchant's profits, but also the expenses of freight and insurance. These cannot with any accuracy be stated.

There

There were brought into England, within the same period, from Germany, 561,604lbs. of wool, not called Spanish, but a great deal of which was of the same quality.

There is the same difficulty with regard to 613,059lbs. of wool imported from Africa and the Cape of Good Hope.

From Portugal there came also 486,124lbs., the greater part of which was probably equal to the third, or even the coarser second sorts of Spanish wool.

From these data, gross as some of them are, little doubt can be entertained, that during the three years in question, Great Britain paid to foreign countries for the wool which was the chief basis of its fine woollen manufactures, at least £4,700,000, or upwards of £1,560,000 per annum.

Having referred to machinery introduced into the wool-combing business, for which several patents have been taken by different persons, we shall give an account of that invented by the very ingenious Mr. Edmund Cartwright, to whom the manufactures of this country are, in many particulars, much indebted. In describing his own machine, Mr. C. says, "it is the first of the kind; at least, all former attempts, if there have been any, must have proved abortive, as, previously to my invention no wool was ever known to have been combed any other way than by the slow and extensive process of hand labour." He then goes on to shew the importance of his machinery from the vast magnitude of the woollen manufactures, stating that there cannot be less than from 3 to 400,000 packs of wool worked up, of which the average expense of combing is estimated at from £800,000 to a million. He says, he obtained his first patent in April, 1790, his second in the December following, but that it was not till nearly two years afterwards that his machine was brought to its then (1792) state of simplicity and perfection. By this invention, the wool, if for very nice operations, goes through three operations, otherwise two are sufficient. The first opens the wool, and makes it unite into a rough sliver, but does not clear it. The clearing is performed by the second, and, if necessary, by a third operation. A set of machinery, consisting of three machines, will require the attendance of one overseer and ten children, and will comb a pack, or 240lbs., in twelve hours. As neither fire nor oil is necessary for machine combing, the saving in these articles will, in general, pay the wages of the overseer and children, so that the actual saving to the manufacturer is the whole of what the combing costs by the old mode of hand-combing. The patentee contends also that machine-*combed* wool is better, especially for machine-*spinning*, by at least twelve per cent.; being all equally mixed, the slivers uniform, and of any required length: and it makes much less noyle than any hand-combing whatever. The machinery invented by Mr. Cartwright may be thus described:—It consists of what he calls, 1st. A crank-lasher; 2d. A circular clearing-comb; and, 3d. A comb-table.

In the crank-lasher there is a tube, through which the material being drawn into a sliver, and slightly twisted, is drawn forward by delivering rollers. There is a wheel fast upon the cross-bar of the crank; and another, on the opposite end of whose axis is a pinion working in a wheel upon the axis of one of the delivering rollers. The clearing-comb, for giving work in the head, is carried in a frame by two cranks. The comb-table having the teeth pointing towards the centre, is moved by cogs upon the rim, and carried round upon trucks, like the head of a wind-mill: in this there are drawing-rollers and conducting-rollers.

To the introduction of this machinery there was a violent opposition, which the inventor naturally expected, as it tended to throw out of employ 50,000 combers, and was likely to ruin all the master wool-combers on a small scale, who, perhaps, had neither property nor enterprise to engage in works so extensive as to afford employment for a set of machinery.

Notwithstanding the introduction of Mr. Cartwright's machines, and others intended for the same purposes, there is still a great deal of wool combed in the old way, in different parts of the kingdom, we shall, therefore, mention a curious custom which still exists among the journeymen in that business. When any of them are out of employ, they set out in search of a master, with a sort of a certificate from their last place. This is called going on the *tramp*, and at every shop at which they call, and can get no work, they receive each a penny, which is given from the common stock *raised by* the workmen in that shop.

The invention of wool-combing is ascribed to Bishop Blaize, who, on that account, is looked up to as the patron saint of the trade, and, in honour of whom, a splendid festival is annually kept by the whole body of wool-combers in this kingdom, on the third of February.

We shall conclude this article, and our volume, with a very brief account of some of the chemical properties of wool.

Some of the simple chemical properties of wool have been examined by M. Achard, and compared with the corresponding properties of the hair of different animals. The copious generation of oxalic acid by treatment of wool with nitric acid, has been particularly described and explained by M. Berthollet, in his beautiful researches on animal matter; and the great solvent power of the caustic fixed alkalies, has been happily applied to some use by M. Chaptal, as a saponaceous compound.

The action of the nitric acid on wool is very curious. When cold, this acid not only disengages a large quantity of azotic gas, but, when warmed, much nitrous gas is given out, and, at least, two new acids are formed, viz., the malic and the oxalic; the latter is in greater abundance than even from sugar and nitrous acid, or any other hydro-carbonous basis. A small scum of a peculiar oil always arises during the action of nitrous acid on these animal substances.

The

The carbonated alkalies have little action on wool, but the caustic fixed alkalies, when digested with it, speedily weaken its fibre, reduce it to a soft gelatinous pulp, and, finally, make a perfect solution. The alkali, at the same time, loses its alkaline properties as it does in common soap. This saponaceous solution of wool is made for experiment in a few minutes by boiling bits of wool or flannel in a caustic alkaline solution; and it has been recommended by Chaptal to be employed instead of common soap in cleansing cotton and other goods in manufactures, as, by this means, a number of refuse bits and clippings of wool and woollen cloth which are now thrown away may be put to some use. This soapy solution does not lather well when agitated with water, nevertheless, it acts very powerfully in cleaning cloth. It has a strong and somewhat offensive smell, which is left at first in the cloth, but goes off by short exposure to the air.

APPENDIX.

PRACTICAL GEOMETRY.

GEOMETRY is the science and doctrine of local extension, of lines, surfaces, and solids, with that of ratios.

The name geometry literally signifies measuring of the earth, as it was the necessity of measuring the land that first gave occasion to contemplate the principles and rules of this art, which has since been extended to numberless other speculations; insomuch, that together with arithmetic, geometry forms now the chief foundation of all the mathematics.

Geometry is distinguished into theoretical or speculative and practical.

Theoretical or speculative geometry, treats of the various properties and relations in magnitudes, demonstrates theorems, &c.

And practical geometry, is that which applies those speculations and theorems to particular uses in the solution of problems, and in the measurements in the ordinary concerns of life, which is the subject of the present article.

We shall now proceed to give the principles of practical geometry, beginning with

GEOMETRICAL DEFINITIONS.—A geometrical point has neither length, breadth, nor thickness. From this definition it may be easily understood that a geometrical point cannot be seen or felt; it can in fact only be imagined. A point is only to mark the place whence a line is to begin, or where it is to end. And this point or mark may be made as small as possible, provided it be still distinct, that the length of lines and their meetings and intersections may appear plainly, and from this sort of convenience has arisen the phrase that is supposed to describe its essence, viz., *that it is without parts.*

This idea has nothing to do with the reasoning; all that is necessary is, that the *point, dot* or *mark* should take up no sensible part of the line, in order that the diagram may be distinct. *Points* then are only subservient to the convenience of construction.

A line is length without breadth or thickness; this definition will present no difficulty, if the preceding be well comprehended; for drawing any line as narrow as convenience will admit, and the geometrical figure or diagram will be the clearer; and there is no necessity to conceive length without breadth.

The extremities of a line are points.

A right line, or what is most commonly called a straight line, is that which traces the shortest distance between its extreme points, or one that tends every where the same way.

A *crooked* line is that which consists of straight lines not continued in the same direction. See *Fig.* 1, *Plate* GEOMETRICAL DEFINITIONS.

A *curved* line is that of which no portion is a straight line. *Fig.* 2.

A plane rectilineal angle is the inclination of two straight lines to one another, which meet together, but are not in the same straight line.

To abridge the reference, it is usual to denote an angle by tracing over its sides; the letter at the vertex, which is common to them both, being placed in the middle.

Thus the angle contained by the straight lines A B and B C, (*Fig.* 3), or the opening formed by the revolution of B A about the point B into the position B C, is named A B C or C B A; or, in short, as the angle B.

Also, *Fig.* 4, there are two angles, and each formed about the point B, and named A B C, C B D, or C B A, D B C.

A right angle is the fourth part of an entire circuit or revolution, as A B C, *Fig.* 5.

The sides of a right angle are said to be perpendicular to each other.

Beginners are sometimes very apt to confound the terms perpendicular, and plumb or vertical line. A line is vertical when it is at right angles to the plane of the horizon, or level surface of the earth, or to the surface of water which is always level. The sides of a house are vertical. But a line may be perpendicular to another, whether it stands upright, or inclines to the ground, or even if it lies flat upon it, provided only that it makes the two angles formed by meeting with the other line equal to each other.

An *acute* angle is less than a right angle. *Fig.* 6.

An

An *obtuse* angle is greater than a right angle. *Fig*. 7.

One side of an angle forms with the other produced a *supplemental* or *exterior angle;* thus the angle A B C, (*Fig*. 8), is supplemental to the angle A B D, and the angle A B D supplemental to the angle A B C.

A *vertical* angle is formed by the production of both its sides; thus in *Fig*. 9, if the sides of the angle D E B are produced to A and C respectively, then D E B, A E C, are called vertical angles, and they are always equal to one another.

Two straight lines are said to be *inclined* to each other, if they meet when produced, and the angle so formed is called their *inclination;* thus in *Fig*. 10, the lines A C, B D, are said to be inclined to each other, because when they are produced they intersect each other in E, and the angle A E B is said to be their *inclination*.

Straight lines which have no inclination are termed *parallel lines*, as *Fig*. 11.

A *figure* is a plane surface included by a linear boundary called its *perimeter*.

Of rectilineal figures the *triangle* is contained by *three* straight lines.

An *equilateral* triangle is that which has all its sides equal; thus in *Fig*. 12, the triangle A B C is said to be equilateral, because the sides A B, B C, and C A, are each equal.

An *isosceles* triangle is that which has only *two* of its sides equal: thus the triangle at *Fig*. 13, is termed isoceles, because the sides A B and A C are equal.

A triangle whose sides are unequal is named *scalene;* thus in *Fig*. 14, the sides A B, B C, and C A are all unequal.

A *right angled* triangle is that which has a right angle; thus in *Fig*. 15, the angle A B C is a right angle.

An *obtuse angled* triangle is that which has an obtuse angle; thus in the triangle A B C, *Fig*. 16, the angle B A C is an obtuse angle.

An *acute angled* triangle is that which has *all* its angles acute. *Fig*. 17.

A *quadrilateral* figure is contained by *four* straight lines.

Of quadrilateral figures, a *square* has one right angle, and all its sides equal. *Fig*. 18.

An *oblong* has one right angle, and its opposite sides equal. *Fig*. 19.

A *rhombus* has all its sides equal. *Fig*. 20.

A *rhomboid* has its opposite sides equal. *Fig*. 21.

A *trapezium* is a quadrilateral which has not its pairs of opposite sides equal. *Fig*. 22.

A *trapezoid* has only one pair of opposite sides parallel. *Fig*. 23.

The straight line which joins obliquely the opposite angular points of a quadrilateral figure, is named a *diagonal;* thus in *Fig*. 24, B D is termed the diagonal.

A rectineal figure having more than four sides, bears the general name of a *polygon*, and receives particular names according to the number of their sides or angles, as pentagon, hexagon, &c.

A *pentagon* is a polygon of five sides, *Fig*. 25; a *hexagon* has six sides, *Fig*. 26; a *heptagon* seven, *Fig*. 27; an *octagon* eight, *Fig*. 28; a *nonagon* nine, *Fig*. 29; a *decagon* ten, *Fig*. 30; an *undecagon* eleven, *Fig*. 31; and a *dodecagon* twelve sides, *Fig*. 32.

A polygon is regular when it has all its sides and all its angles equal. If they are not both equal, the polygon is irregular.

An equilateral triangle is also a regular figure of three sides, and the square is one of four; the former being called a *trigon*, and the latter a *tetragon*.

A circle is a plane figure described by the revolution of a straight line about one of its extremities.

The fixed point is called the *centre* of the circle; the describing line its *radius*, and the boundary traced by the remote end of that line its *circumference;* thus in *Fig*. 33, the point B is the centre, and A B the radius.

The diameter of a circle is a right line drawn through the centre, and terminating in the circumference on both sides; thus in *Fig*. 34, the line C E D passes through the centre E, and is terminated by the circumference.

An *arc of a circle* is any part of its circumference.

A *chord* is a right line joining the extremities of an arc; thus *Fig*. 35, A B is the chord.

A *segment* is any part of a circle bounded by an arc and its chord; thus A is a segment in *Fig*. 36.

A *semicircle* is half the circle, or a segment cut off by a diameter; so in *Fig*. 37, A is a semicircle.

A *sector* is any part of a circle bounded by an arc, and two radii drawn to its extremities; see B, *Fig*. 38.

A *quadrant* or quarter of a circle, is a sector having a quarter of the circumference for its arc, and its two radii are perpendicular to each other. *Fig*. 39, A C, C D are perpendicular to each other; and the arc A B D is a quarter of the whole circumference.

A *tangent* is a straight line, drawn so as just to touch against a circle without cutting it, as A C B, *Fig*. 40. The point A when it touches the circle is called the point of contact. And a tangent cannot touch a circle in more than one point.

The base of a figure is the side on which it is supposed to stand erect, as A B in *Figs*. 41 and 42.

The altitude of a figure is its perpendicular height from the base to the highest part, as C D in *Figs*. 41 and 42.

A *solid* is any body that has length, breadth and thickness. A book, for instance, is a solid; so also is a sheet of paper; for though its thickness is very small, yet it possesses some thickness. The boundaries of a solid are surfaces.

Similar solids are such as are bounded by an equal number of similar planes.

A prism is a solid, of which the sides are parallelograms, and the two ends or bases are similar polygons, parallel to each other. Prisms are denominated according

according to the number of angles in the base, triangular prism, quadrangular, heptangular, and so on. *Fig.* 43 is a triangular prism.

Figs. 44, 45 and 46 are quadrangular prisms, usually termed parallelopipeds.

A rhomboid is an oblique prism, whose bases are parallelopams. *Fig.* 47.

A cylinder is a solid (*Figs.* 48, 49,) formed or generated by the rotation of a rectangle about one of its sides, supposed to be at rest; this quiescent side is called the axis of the cylinder. Or it may be conceived to be generated by the motion of a circle in a direction perpendicular to its surfaces, and always parallel to itself.

A cylinder is either right or oblique, as the axis is perpendicular to the base or inclined; thus *Fig.* 48 is a right and *Fig.* 49 an oblique cylinder.

Fig. 50 represents a hollow cylinder; it may be conceived to be formed by boring a hole through the centre of a cylinder.

Fig. 51 represents the section of a cylinder cut off by a plane parallel to the axis.

Fig. 52 represents the sector of a cylinder contained by two planes forming an angle, and the curved surface of the cylinder; the line of concourse of the planes being parallel to the axis of the cylinder.

A pyramid (*Figs.* 55, 56 and 57,) is a solid bounded by or contained within a number of planes, whose base may be any polygon, and whose faces are terminated in one point, commonly called the vertex of the pyramid.

When the figure of the base is a triangle, it is called a triangular pyramid; when the base is a quadrilateral, it is called a quadrilateral pyramid, and so on.

A pyramid is either regular or irregular, according as the base is regular or irregular.

A pyramid is also right or upright, or it is oblique. It is right, when a line drawn from the vertex to the centre of the base is perpendicular to it, as *Figs.* 55 and 56; and oblique when this line inclines, as in *Fig.* 57.

A *cone* is a solid (*Figs.* 58, 59,) having a circle for its base, and its sides a convex surface, terminating in a point, called the vertex or apex of the cone. It may be conceived to be generated by the revolution of a right angled triangle about its perpendicular.

A line drawn from the vertex to the centre of the base is the axis of the cone.

When this line is perpendicular to the base, the cone is called an upright, or right cone, as *Fig.* 58; but when it is inclined it is called an oblique cone, as *Fig.* 59.

If it be cut through the axis from the vertex to the base, the section will be a triangle.

If a right cone be cut by a plane at right angles to the axis, the section will be a circle.

If it be cut oblique to the axis, and quite across from one side to the other, the section will be an *ellipsis*, as *Fig.* 60.

When the section is made parallel to one of the sides of the cone, as *Fig.* 61, the curve which bounds the section is a *parabola*.

When the section is taken parallel to the axis, as *Fig.* 62, the curve is called an hyperbola.

These curves, which are formed by cutting a cone in different directions, have various properties, which are of great importance in astronomy, gunnery, perspective and many other sciences. Their description in plans are exhibited in Problems 27, 28, 29 and 30, of Practical Geometry.

A *sphere* is a solid, terminated by a convex surface, every point of which is at an equal distance from a point within, called the centre, *Fig.* 63.

It may be conceived to be formed by making a semicircle revolve round its diameter. This may be illustrated by the process of forming a ball of clay by the potter's wheel, a semicircular mould being used for the purpose. The diameter of the semicircle round which it revolves, is called the axis of the sphere.

The ends of the axis are called poles.

Any line passing through the centre of the sphere, and terminated by the circumference, is a diameter of the sphere.

Every section of a sphere is a circle; every section taken through the centre of the sphere is called a great circle; every other is called a lesser circle.

Any portion of a sphere cut off by a plane, is called a segment; and when the plane passes through the centre, it divides the sphere into two equal *parts*, each of which is called a hemisphere.

A *spheroid* is a solid, (*Fig.* 64,) generated by the rotation of a semi-ellipsis about the transverse or conjugate axis; and the centre of the ellipsis is the centre of the spheroid.

The line about which the ellipsis revolves, is called the axis. If the spheriod be generated about the conjugate axis of the semi-ellipsis, it is called *prolate* spheroid.

If the spheroid be generated by the semi-ellipses revolving about the transverse axis, it is called an *oblong* spheroid.

Every section of a spheroid is an ellipsis, except when it is perpendicular to that axis about which it is generated; in which case it is a circle.

All sections of a spheroid parallel to each other, are similar figures.

A frustrum of a solid means a piece cut off from the solid by a plane passed through it, usually parallel to the base of the solid, as the frustrum of a cone, a pyramid, &c. &c.

There are a lower and an upper frustrum, according as the piece spoken of does or does not contain the base of the solid.

Ratio is the proportion which one magnitude bears to another of the same kind, with respect to quantity, and is usually marked thus, A : B.

Of these, the first is called the antecedent, and the second the consequent.

The

The measure or quantity of a ratio is conceived by considering what part of the consequent is the antecedent; and it is obtained by dividing the consequent by the antecedent.

Three magnitudes or quantities, A, B, C, are said to be proportional, when the ratio of the first to the second is the same as that of the second to the third. Thus 2, 4, 8 are proportional, because 4 is contained in 8, as many times as 2 is in 4.

Four quantities A, B, C, D, are said to be proportional, when the ratio of the first A to the second B is the same as the ratio of the third C to the fourth D. It is generally written A : B : : C : D, or if expressed in numbers 2 : 3 : : 4 : 6.

Of three proportional quantities, the middle one is said to be a mean proportional between the other two; and the last a third proportional to the first and second.

Of four proportional quantities, the last is said to be a fourth proportional to the other three taken in order.

Ratio of equality is that which equal numbers bear to each other.

Inverse ratio is when the antecedent is made the consequent, and the consequent the antecedent. Thus if 2 : 4 : : 6 : 12, then inversely 4 : 2 : : 12 : 6.

Alternate proportion is when antecedent is compared with antecedent, and consequent with consequent. Thus if 4 : 2 : : 12 : 6, then by alternation 4 : 12 : : 2 : 6.

Proportion by composition is when the antecedent and consequent, taken as one quantity, are compared either with the consequent or with the antecedent. Thus if 4 : 2 : : 12 : 6, then by composition 4+2 : 2 : : 12+6 : 6, and 4+2 : 4 : : 12+6 : 12.

Divided proportion is when the difference of the antecedent and consequent is compared either with the consequent or with the antecedent. Thus if 3 : 2 : : 9 : 6; then by division 3—2 : 2 : : 9—6 : 6, and 3—2 : 3 : : 9—6 : 9.

Continued proportion is when the first is to the second as the second to the third; as the third to the fourth; as the fourth to the fifth; and so on.

Compound ratio is formed by the multiplication of several antecedents and the several consequents of ratios together, in the following manner:

If A be to B as 3 to 5, B to C as 5 to 8, and C to D as 8 to 6; then A will be to D as $\frac{3\times5\times8}{5\times8\times6}=\frac{120}{240}=\frac{1}{2}$ that is A : D : : 1 : 2.

Bisect means to divide any thing into two equal parts.

Trisect is to divide any thing into three equal parts.

Inscribe, to draw one figure within another, so that all angles of the inner figure touch either the angles, sides, or planes of the external figure.

Circumscribe, is to draw a figure round another, so that either the angles, sides, or planes of the circumscribing figure, touch all the angles of the figure within it.

Rectangle under any two lines, means a rectangle which has two of its sides equal to one of the lines, and two of them equal to the other. Also the rectangle under A B, C D, means A B $\times$ C D.

An *axiom* is a manifest truth, not requiring any demonstration.

Postulates are things required to be granted true, before we proceed to demonstrate a proposition.

A *proposition* is when something is either proposed to be done, or to be demonstrated, and is either a problem or a theorem.

A *problem* is when something is proposed to be done, as some figure to be drawn.

A *theorem* is when something is proposed to be demonstrated or proved.

A *lemma* is when a premise is demonstrated, in order to render the thing in hand the more easy.

A *corollary* is an inference drawn from the demonstration of some proposition.

A *scholium* is when some remark or observation is made upon something mentioned before.

The sign = denotes that the quantities betwixt which it stands are equal

The sign + *(plus)* denotes that the quantity after it is to be added to that immediately before it.

The sign — *(minus)* denotes that the quantity after it is to be taken away, or subtracted from the quantity, preceding it.

Practical Geometry.

Problem 1. To bisect a given angle.

In A B, *Fig.* 1, take any two points B, D; from A E cut off A C equal to A B, and A E to A D; join the alternate lines B E and D C intersecting in the point F; join A F and it will bisect the angle D A E as required.

Otherwise: In *Fig.* 2, take A B and A C equal to each other; and from these points as centres, and with any distance as radius describe two arcs intersecting each other in D; join D A and it will bisect the angle B A C as required.

Problem 2. To bisect a given finite straight line.

Let A B, *Fig.* 3, be the right line which it is required to bisect; and from one of its extremities as A, draw A F forming any angle with A B; and make A C=C D=D F of any convenient length; join F B and continue it beyond B till B G be equal to B F; lastly, join G C which will bisect A B in the point E.

Otherwise: From the points A and B as centres, *Fig.* 4, and with any distance or opening of the compasses, greater than half A B, describe arches intersecting each other in C and D. Draw the line C D; and the point E, where it cuts A B, will be the middle as required.

Problem 3. Through a given point, to draw a line parallel to a given straight line.

Let A B, *Fig.* 5, be the given line, and F the given point. In A B take any two points C, D; join F C which

which produce till C E be equal to it; again join E with the point D, and continue till D G be equal to D E; then F G being joined, will be parallel to A B.

Otherwise: In *Fig.* 6, take any point D in the proposed line, and with the centres C, F, and distance C F, describe the arcs F D, C G; then again with centre C and distance C G equal to D F describe another arc, intersecting the arc C G in G; join F G, and it will be parallel to A B.

Problem 4. From a point in a given straight line, to erect a perpendicular.

In *Fig.* 7, let C be the proposed point, and A B the straight line. In A B take any other point D, and draw D E equal to D C, forming with A B any angle whatever; join E C and produce it until C E be equal to C D or D E; make C G equal to C E; join G E and produce this till F E be equal to C E; join F C, and it will be perpendicular to A B.

Otherwise: In *Fig.* 8, take C D equal to C E, and with centres D and E, and any convenient distance greater than C E or C D, describe two arcs intersecting each other in F; join F C and it will be perpendicular to A B, as was required.

Again, when the point is near the extremity of the line, as in *Fig.* 9, take any point D above the line, and with centre D and distance D C describe the circular arc A C F meeting A B again in A; join A D and produce it to meet the circular arc in F; join F C and it will be the required perpendicular.

Another method, when the proposed point C is at the extremity of the given straight line, *Fig.* 10, in A C take any other point B; and with centres B and C and distance equal to B C describe two arcs intersecting each other in D; join B D which produce till D F = B D; join F C and the thing required is done.

Problem 5. To let fall a perpendicular upon a given straight line, from a point without it.

In *Fig.* 11, let F be the point and A B the line. In this line take any point D; and draw D G obliquely, and make D H = D G = D E; join G H and produce it till H I be equal to H E; make H K = H G join I K, and (*Problem* 3) draw F C parallel to it: F C is the perpendicular required.

Again, *Fig.* 12, with centre F and any radius describe the arc E D cutting A B in E, D; from these points with the same or any other distance, describe arcs intersecting each other as in G; join G F meeting A B in C, and F C will be the perpendicular required.

Problem 6. To make an angle equal to another given angle.

Let A B C, *Fig.* 13, be the proposed angle; from the point B with any radius describe the arc A C cutting A B, B C, in the points A C. Draw the line D F; and from the point D with a radius equal to B C describe the circular arc E F; and then from F with a radius equal to C A describe another arc intersecting the former in E; join D E which will be the angle required.

Problem 7. To divide a given line A B into any proposed number of equal parts.

From A, one end of the line A B, *Fig.* 14, draw A 3 forming an angle with A B; and from B the other extremity of the given line, draw B 4, making the angle A B 4 equal to B A 3 by the preceding problem. In each of these lines A 3, B 4, beginning at A and B, set off as many equal parts of any length as A B is to be divided into; join the points 1, 4; 2, 5; and 3, 6. and A B will be divided, as was required.

Problem 8. To find the centre of a given circle, or of any one already described.

In *Fig.* 15, draw any chord A B which bisect with the perpendicular diameter D E; divide D E into two equal parts in the point C; then will C be the centre of the circle.

Problem 9. To draw a tangent to a given circle that shall pass through a given point A.

From the centre O, *Fig.* 16, draw the radius O A; then through the point A draw B C perpendicular to O A, and it will be the tangent required.

Problem 10. To draw a tangent to a circle from a given point A without it.

Find the centre C, *Fig.* 17, of the given circle; and join A C, and on it as a diameter describe the circle A B C D intersecting the given circle in the points B, D; join A B, A D, and they will be tangents to the required circle.

Problem 11. Given three points A, B, C, not in a straight line, to describe a circle that shall pass through them.

Join A B, B C, *Fig.* 18, and bisect each of them with the perpendiculars *a b*, *c d*, intersecting O; from O with the distance O A, O B, or O C, describe a circle which will pass through the given points.

Problem 11*. To describe the segment of a circle to any length A B and height C D, *Fig.* 19.

Bisect A B by the perpendicular D O, and make D C equal to the given height of the segment; join A D, which bisect by the perpendicular E O, meeting D O in O; with centre O and distance O A or O D describe the circular arc A D B meeting A B in B, and the thing required is done.

Problem 12. On a given straight line, to describe a segment of a circle, that shall contain an angle equal to a given angle.

Let A B be the given line, and C the given angle; (*Fig.* 20). Draw A D, making an angle B A *D* equal to C; erect also A E perpendicular to A D, and draw E F to bisect A B at right angles, and meeting A E in E, and from this point as a centre, and with the distance E A describe the required segment.

Problem 13. In a given triangle to inscribe a circle.

Bisect any two angles A and C (*Fig.* 21), with the lines A D and D C; from D, the point of intersection,

tion, let fall the perpendicular D E; it will be the radius of the circle required.

Problem 14.—In and about a given circle, to inscribe and circumscribe a square.

1st. To inscribe a square in a given circle.

Draw the diameter F G, and through the centre H draw the perpendicular E H I; join E G, E F, F I, and I G. The inscribed figure E F G I is a square.

2d. To circumscribe a square about a given circle.

At the extremities E, F, G, I, of the diameters E I, F G, let tangents be drawn intersecting each other in the points A, B, C, D, which will form the required square.

Problem 15.—About, and in, a given square, to circumscribe and inscribe a square.

1st. Let A B C D (*Fig.* 23) be the proposed square, join the diagonals A D, C B, intersecting each other in the point H; and from that point with the distance H A, describe the circle A B C D. This circle will circumscribe the square.

2d. To inscribe a circle in the square A B C D.

From H, the intersection of the diagonals, let fall the perpendicular H E; then, with H, as a centre and distance H E, describe a circle which will touch the given square internally.

Problem 16.—To construct a triangle, of which the three sides are given (*Fig.* 24).

Let A, B and C denote the sides of the triangle; draw D E equal to A: and with D, as a centre and distance equal to B, describe an arc; then, with centre E, and distance E F, equal to C, describe another arc intersecting the former in F, join D F, E F, and D E F will be the triangle required.

Problem 17.—On a given finite straight line to construct a square.

In *Fig.* 25, let A B represent the proposed line. From the extremity B, draw B D, perpendicular to B A, and equal to it; and from the points A and D, with the distance B A or B D, describe two circles intersecting each other in the point C; join A C and D C; the quadrilateral figure A B C D is the square required.

Problem 18.—To describe any regular polygon, the sides of which shall be equal to a given line.

Set the given line upon any other convenient line, and with a radius equal to the given line describe a semicircle. Divide the semi-circle into as many equal parts as there are to be sides in the polygon; then the half of the diameter is one side of the polygon; through the centre of the semi-circle, and through the second division from the other end of the diameter draw another right line, which will form an adjoining side to the former; bisect each of these adjoining sides by perpendiculars, and the meeting of these perpendiculars will give the centre of a circle, which will contain the given straight line.

Fig. 26, is an example of a hexagon.

Fig. 27, is an example of a heptagon.

Problem 19.—To inscribe a polygon in a given circle.

Draw the diameter of the circle, and another diameter at right angles, produce this last diameter so that the part produced shall be three-fourths of the radius; divide the first diameter into as many equal parts as the polygon is to consist of sides, through the second division, and the extremity of the part produced of the other diameter, draw a line to cut the circumference without the points; the chord of the arc intercepted between the point in the diameter, applied successively to the arc, as other chords, will form the polygon required.

Fig. 28, is an example of a pentagon.

Fig. 29, is an example of a decagon.

Problem 20.—A square being given to form an octagon, of which four of the sides at right angles to each other, shall be common to the middle parts of the sides of the square.

In *Fig.* 30, let A B C D represent the given square, and draw the diagonals A C, B D intersecting each other in E; then, with the points A, B, C, D, as centres, and distances, A E, B E, C E, or D E, describe the arcs G E M, N E K, L E H, and I E F, intersecting the sides of the square in the points F, G, H, I, K, L, M, N; join G H, I K, L M and N F, and F G H I K L M N will be the polygon required.

Problem 21.—To make a triangle equal and similar to a given triangle.

Let the triangle A B C, *Fig.* 31, represent the given one, and take the line D F equal to A C; then with centres D and F, and distances A B, C B describe two arcs intersecting each other in E; join D E, F E, and D E F will be a triangle equal and similar to A B C.

Problem 22.—To make a trapezium equal and similar to a given trapezium.

Divide A B C D the proposed trapezium into two parts by the diagonal B C; make E G equal to B C, and on it construct the two triangles E F G, E H G, by the preceding problem; then will E F G H be the required trapezium.

Problem 23.—To make a square equal to two given squares.

In *Fig.* 33, make the sides A B, B C of the two given squares D and E, form the sides of a right-angled A B C; draw the hypothenuse A C, and on it describe the square F which will be the one required.

Problem 24.—Between two given lines A and B, (*Fig.* 34) to find a mean proportional.

Draw the right line E C, in which take E F equal to A, and F C equal to B; on E C describe a semicircle, and draw F D perpendicular to E C, intersecting the circumference in D; then will F D be the mean proportional required.

Problem 25.—To find a fourth proportional to three given straight lines.

Let A, B and C, *Fig.* 35, be the three given straight lines. Draw the diverging lines H E and H D, in which take H F equal to A, H C to B, and H E to C; join F C, and through E draw E D parallel to F C, meeting H D in D; E D is a fourth proportional to the three straight lines A, B and C.

Problem

Problem 26.—To cut a given straight line into segments which shall be proportional to those of a divided straight line.

Let A K be a straight line, which it is required to cut into segments proportional to those of a given divided straight line.

Draw the diverging line A H, and make A B, B D, D F and F H equal respectively to the segments of the divided line; join H K and draw F G, D E and B C, parallel to it, and meeting A K in G, E and C; then is A K cut in those points proportionally to the segments of A H.

Problem 27.—The transverse and conjugate axes A B and F G, of an ellipsis being given, to find the two foci, and from thence to describe the ellipsis, *Fig.* 37.

Take the semi-transversal A C or C B, and from F, as a centre, describe two arcs cutting A B in D and E, which are the foci required.

In these points fix pins, and then a string being stretched about the points D F E, the point F is caused to move round the fixed points D and E, keeping the string tight, and it will describe an ellipsis as required.

Problem 28.—The same being given as in the preceding problem, to describe an ellipsis, by an instrument called a trammel.

The trammel, as used by artificers, consists of two rules, with a groove in each, so that the grooves may be at right angles to each other; to this there is a rod, with two moveable nuts, and another fixed at the end, with a hole through it to hold a pencil. On the under side of the sliding nuts are two round pins, made to fill the groove of the trammel, and is used as follows:—

OPERATION.

Set the distance of the first pin at B, from the pencil at C to half the shortest axis, and the distance of the second pin at A, to half the longest axis; the pins being put in the grooves, as is shown in the figure; then move the pencil at C, and it will describe the required figures.

Problem 29.—To describe a parabola, having given the position of its directrix D E, and its focus F.

Take a thread equal in length to C A, the end of a square D C A, and fix one end of it at F, and the other end at A; then, if the side D C of the square be moved along the right line D E, and if the point B be always kept close to the edge C A of the square, keeping the string tight, the point or pin B will describe the required parabola.

Problem 30.—Having given the transverse diameter and the foci of two hyperbolas to describe an hyperbola.

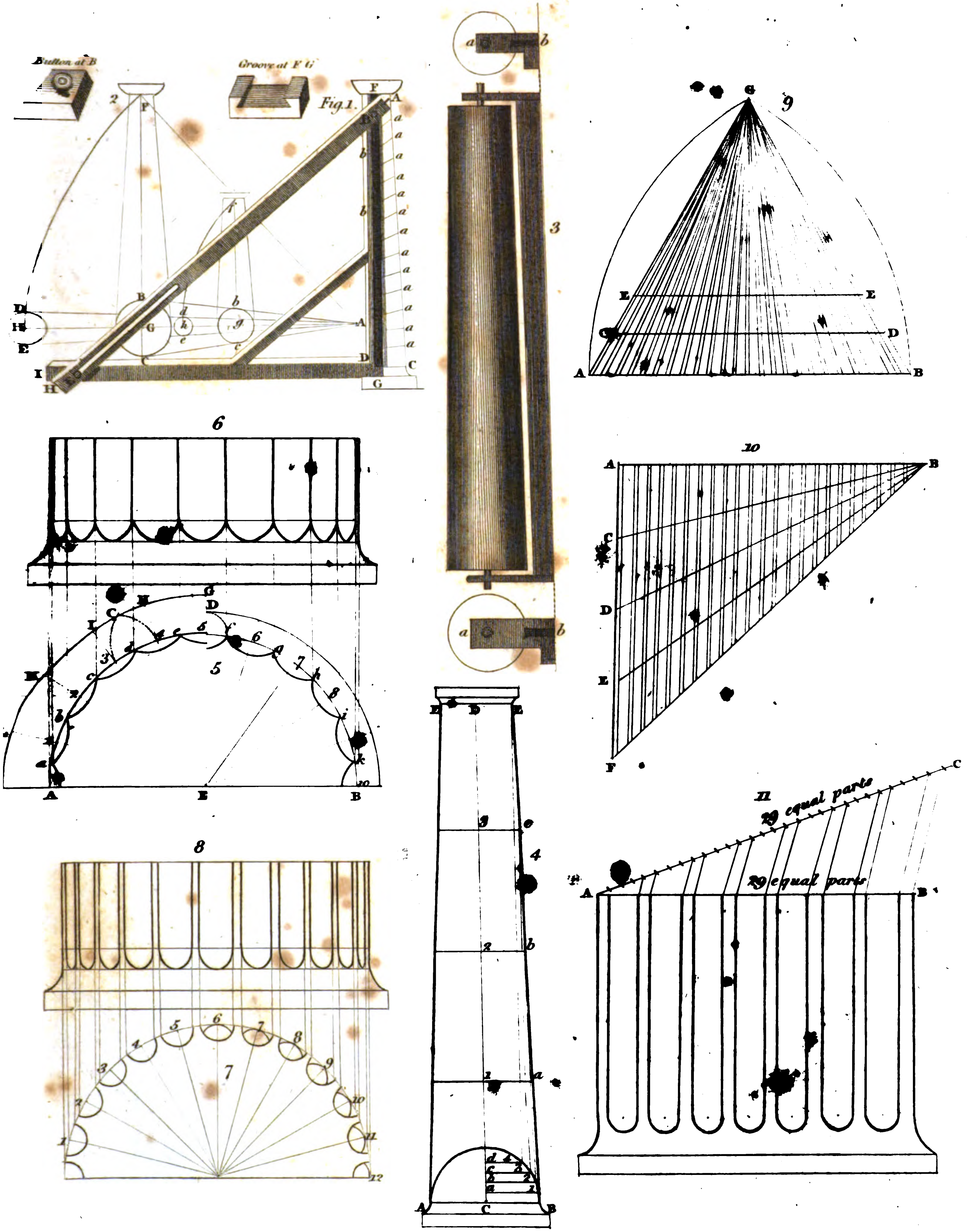
Let A B denote the transverse axis, and F and C the foci, and let a rule be made moveable about the point C, and a string H G F tied to the other end of the rule and to the point F; then, if the point H is moved round the centre C, the angle G of the string H G F, by keeping it always tight and close to the edge of the rule H C, will describe the required hyperbola.

But, if the above order be reversed, and the end C of the rule be fixed in the point F, and the end F of the string in the point C, and a similar operation be repeated as described above, another line, opposite to the former, will be described, which will be another hyperbola, and they both together are called opposite hyperbolas.

We would direct the inquiring student, who wishes to pursue farther the interesting subject of *Geometry* with its applications, to the excellent edition of *Euclid*, by *Dr. Robert Simson*, and to the other Elementary Treatises by *Emerson*, *Thomas Simpson*, *Bonnycastle*, and *Leslie*, and, for the Conic Sections, to the treatises by *Hamilton*, *Simson*, *Robertson*, and *Newton;* the last of which is, in the writer's opinion, one of the best that has yet been presented to the scientific world.

FINIS.

J. M'Creery, Printer,
Black-Horse-Court, London.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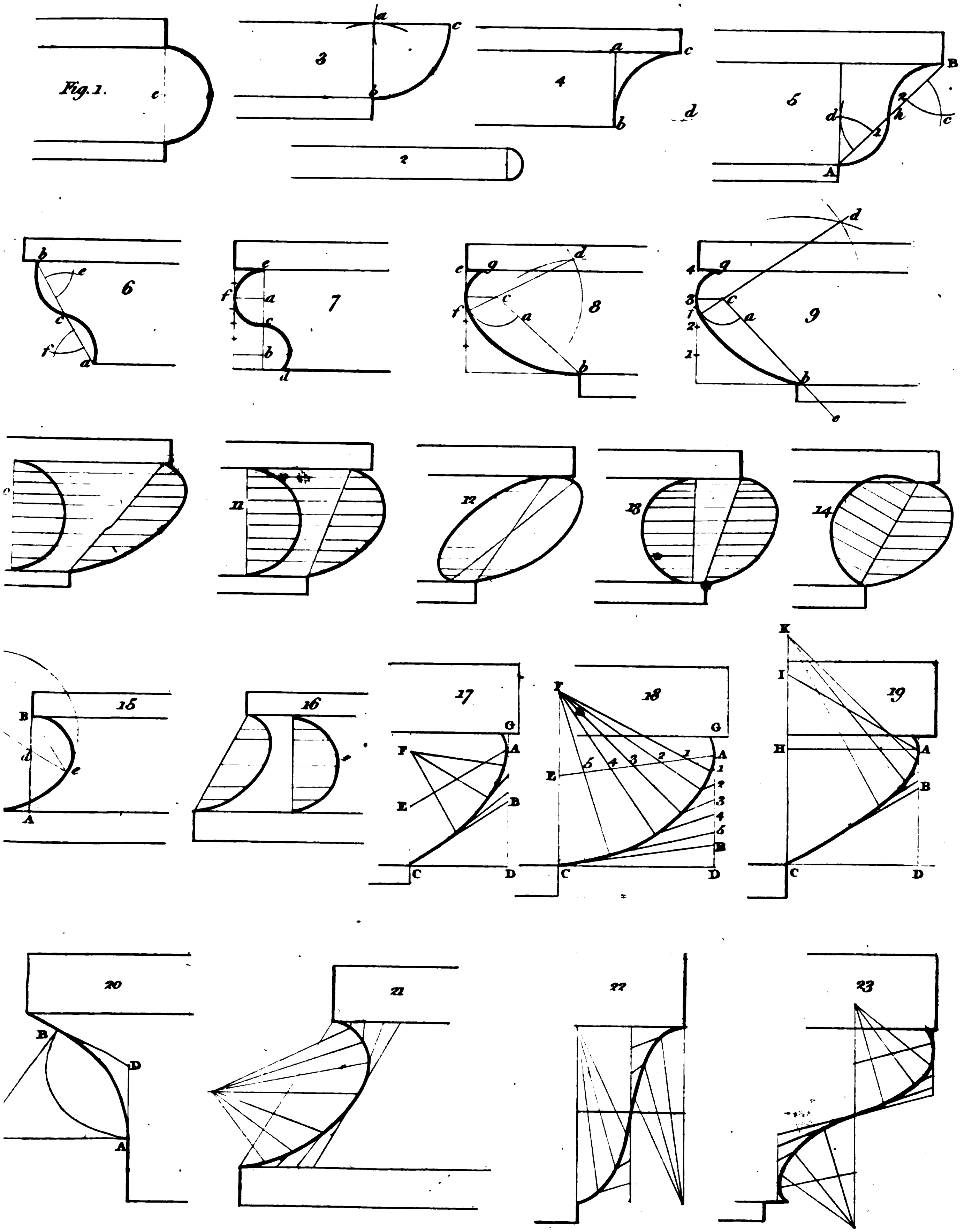
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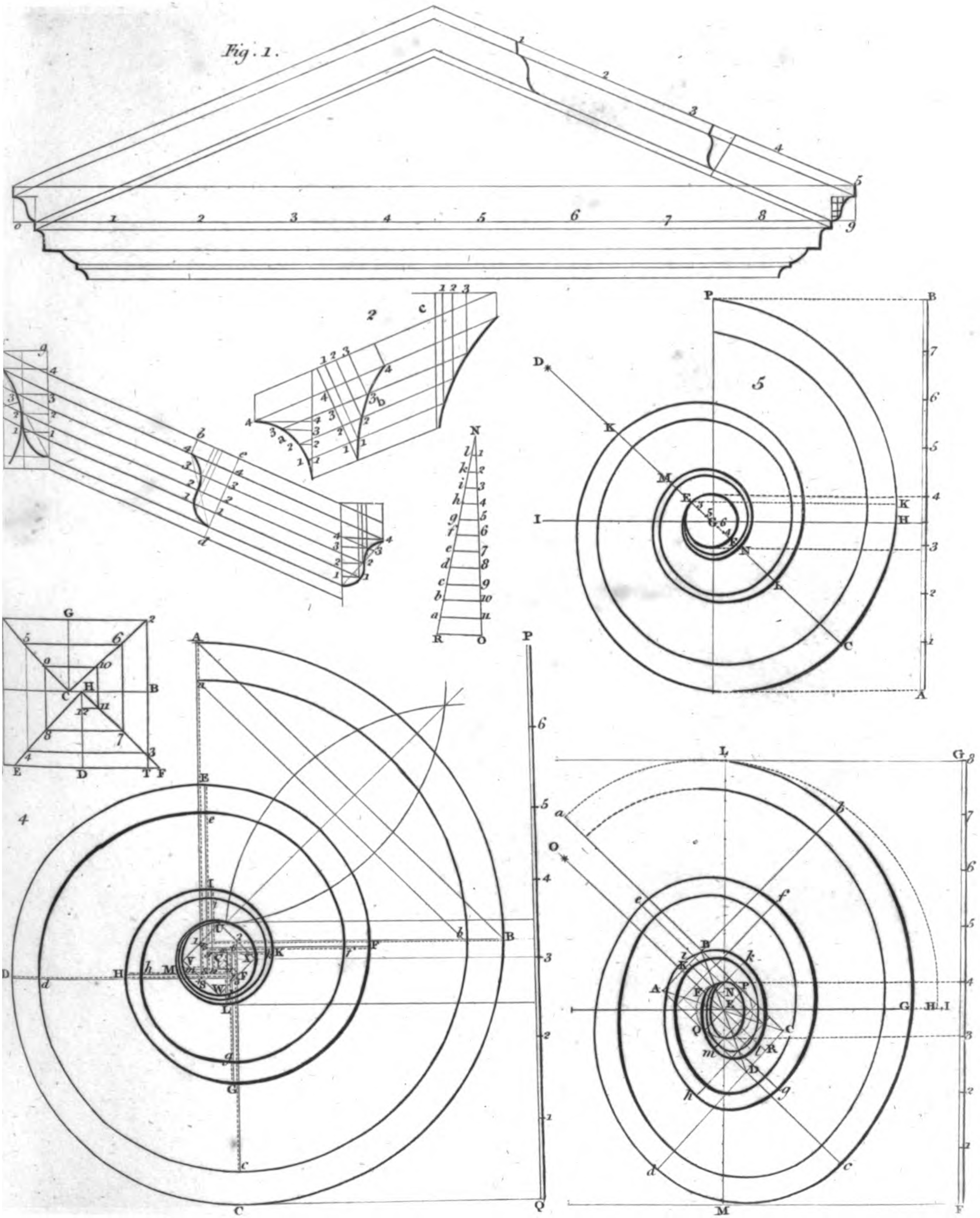
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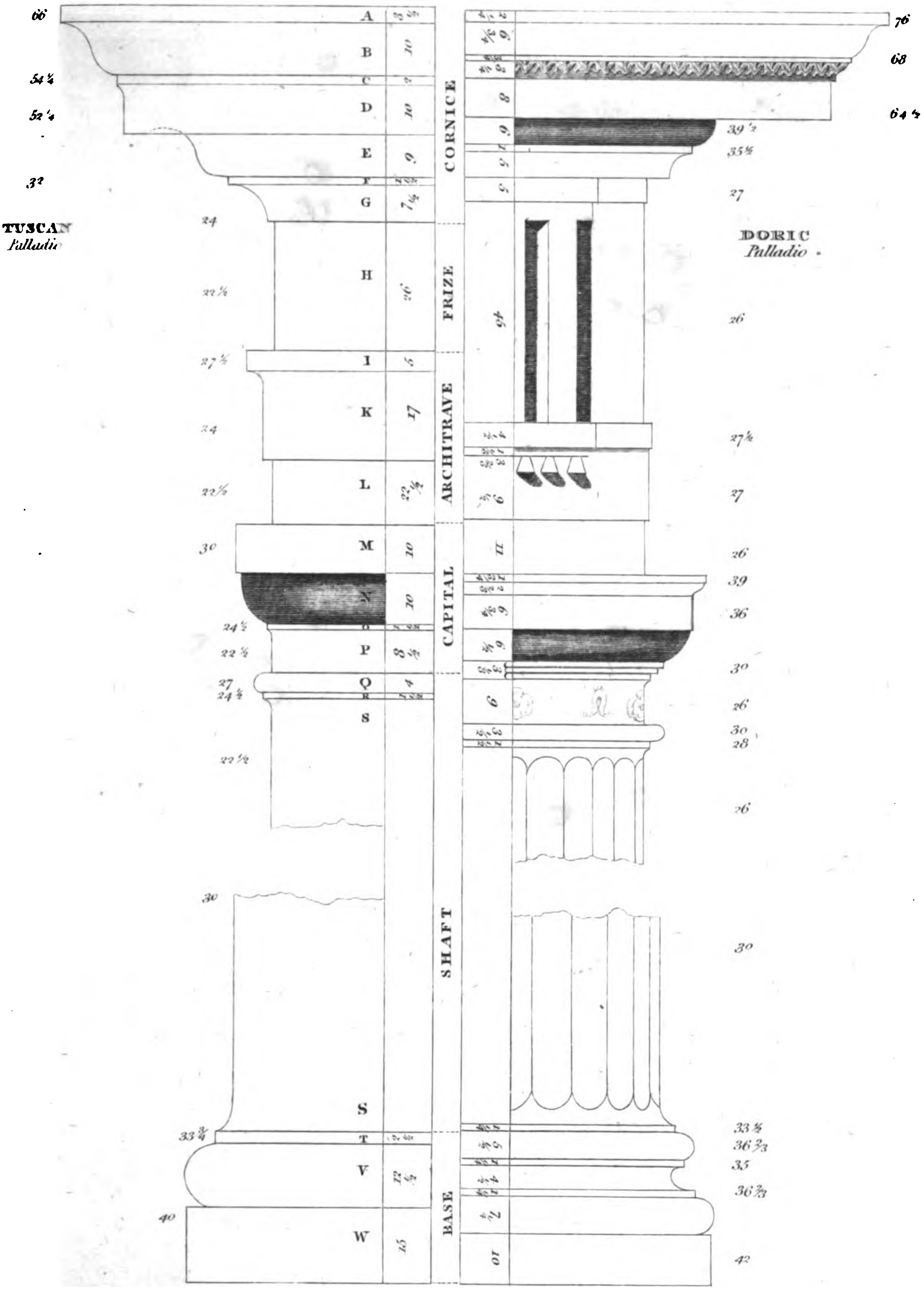
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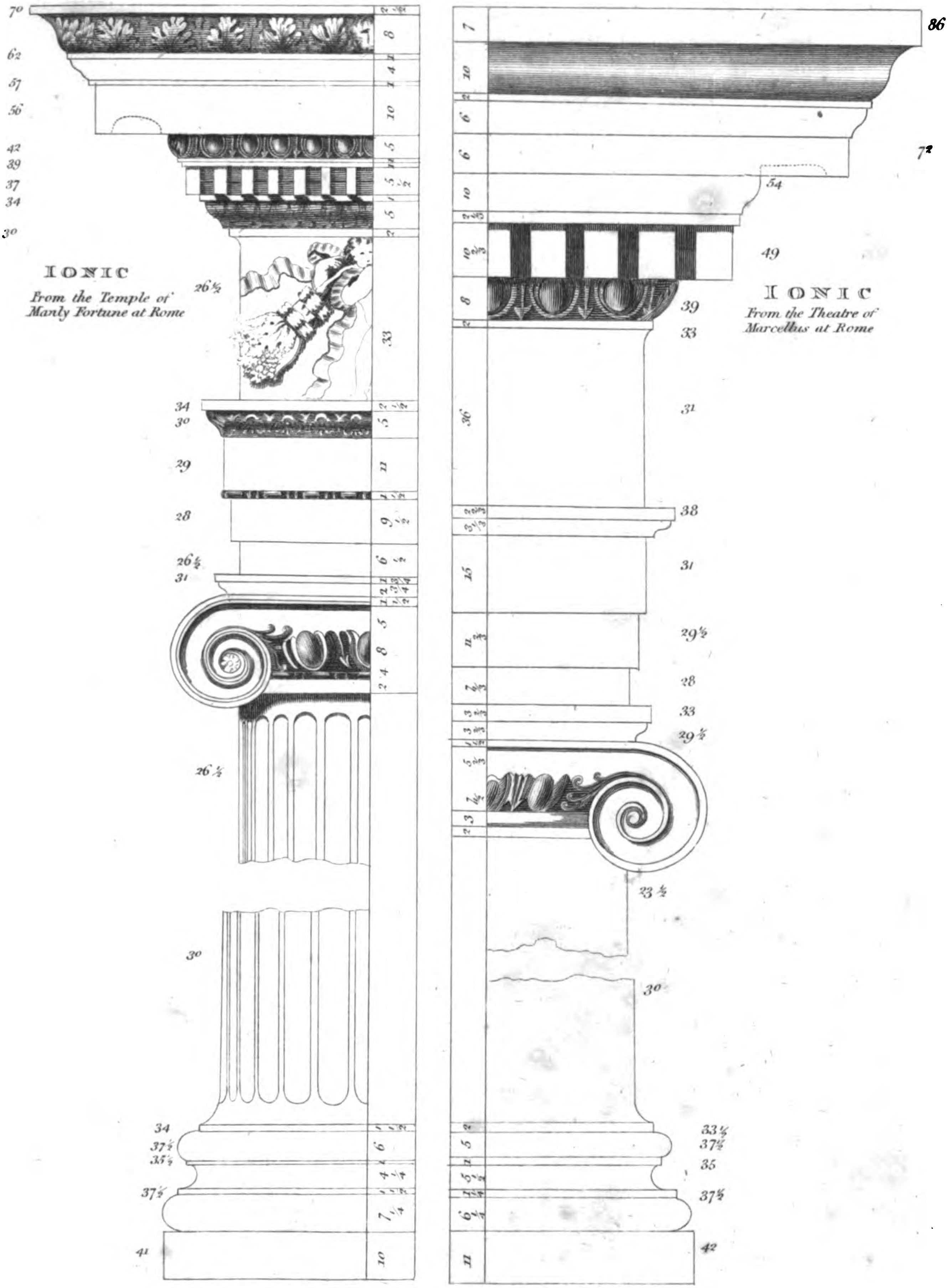
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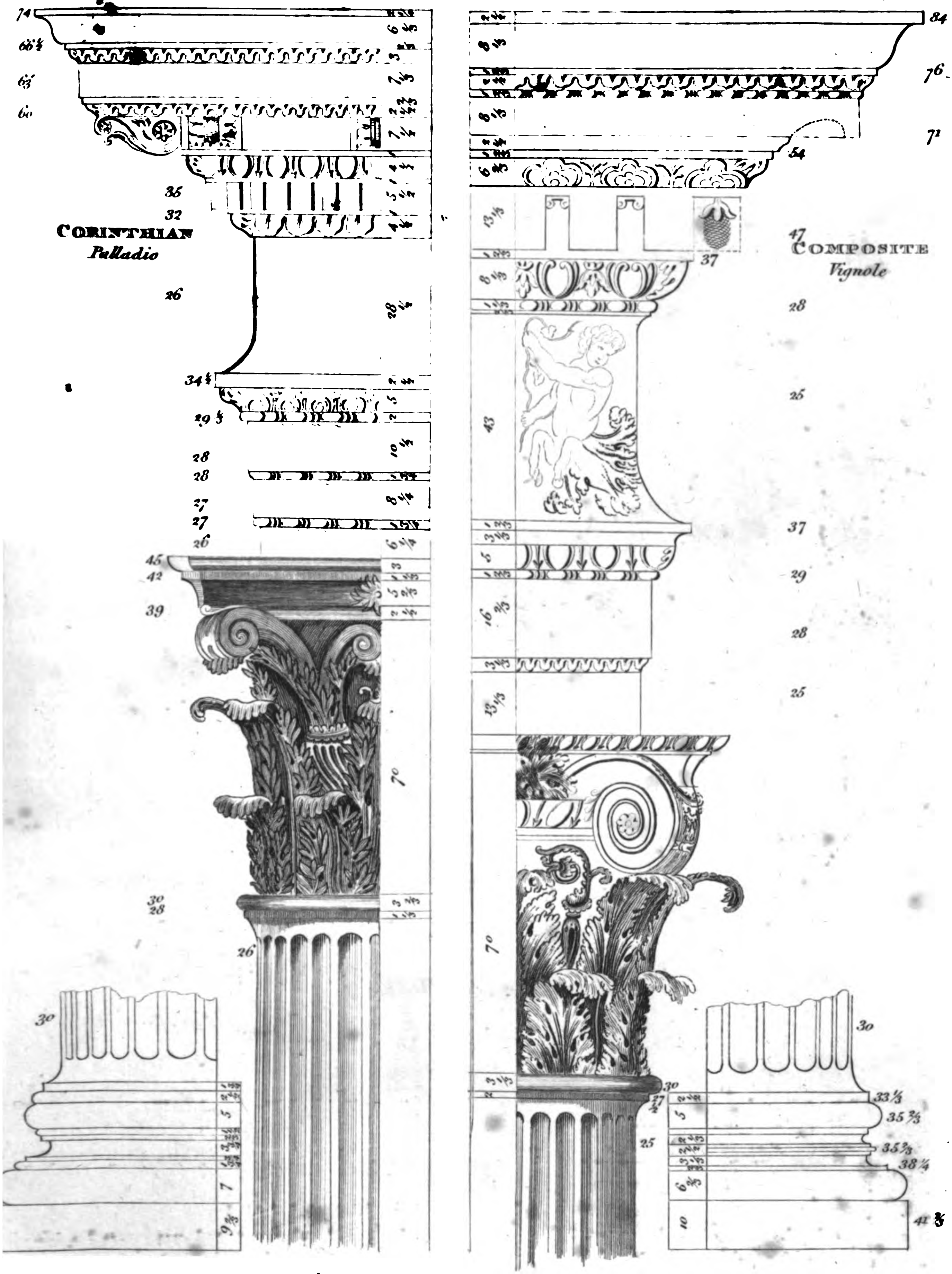
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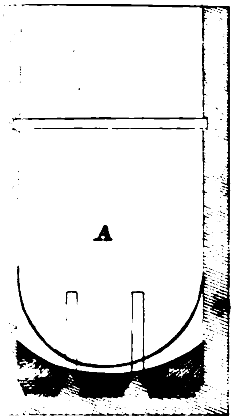

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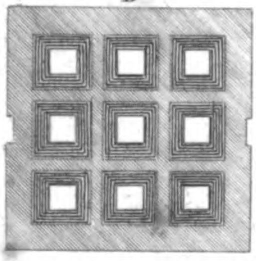

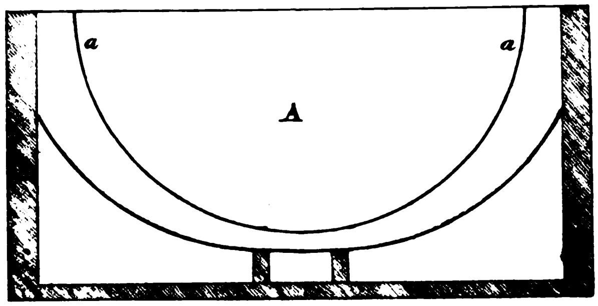

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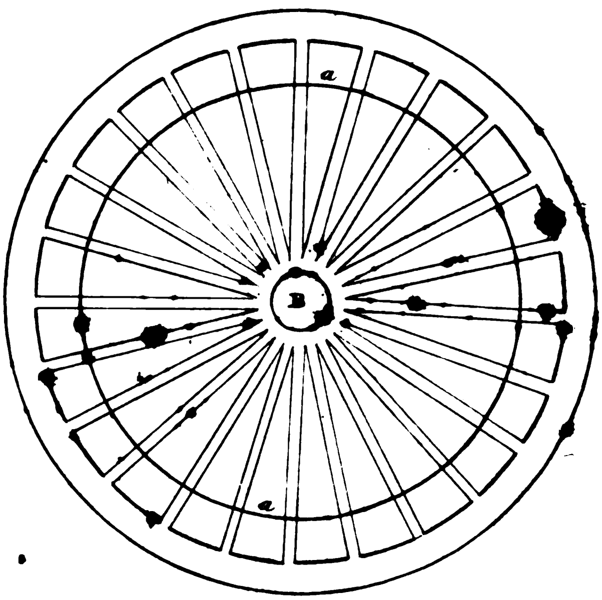

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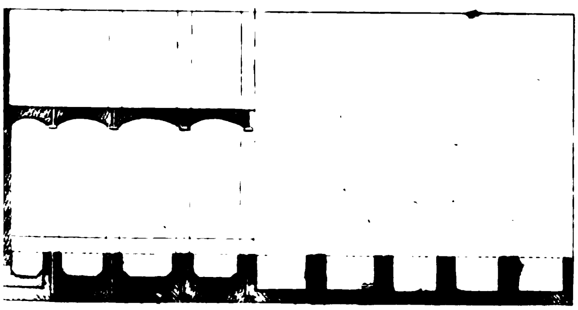

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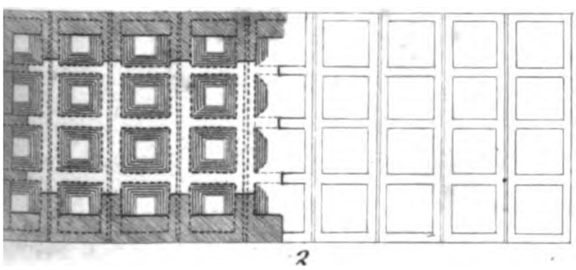

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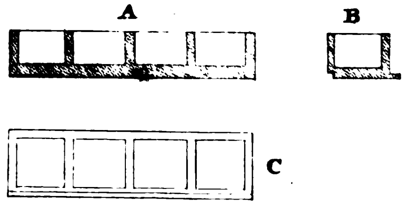

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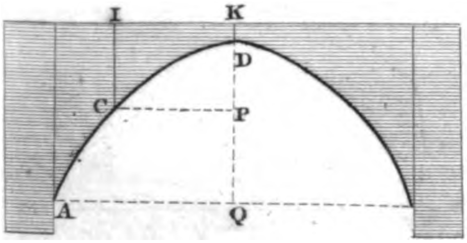

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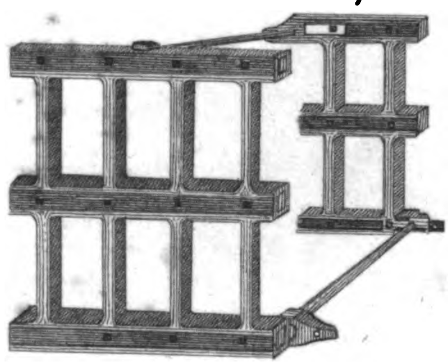

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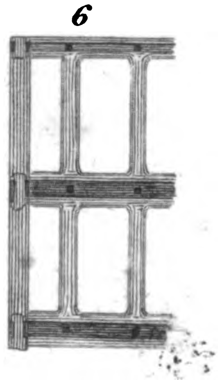

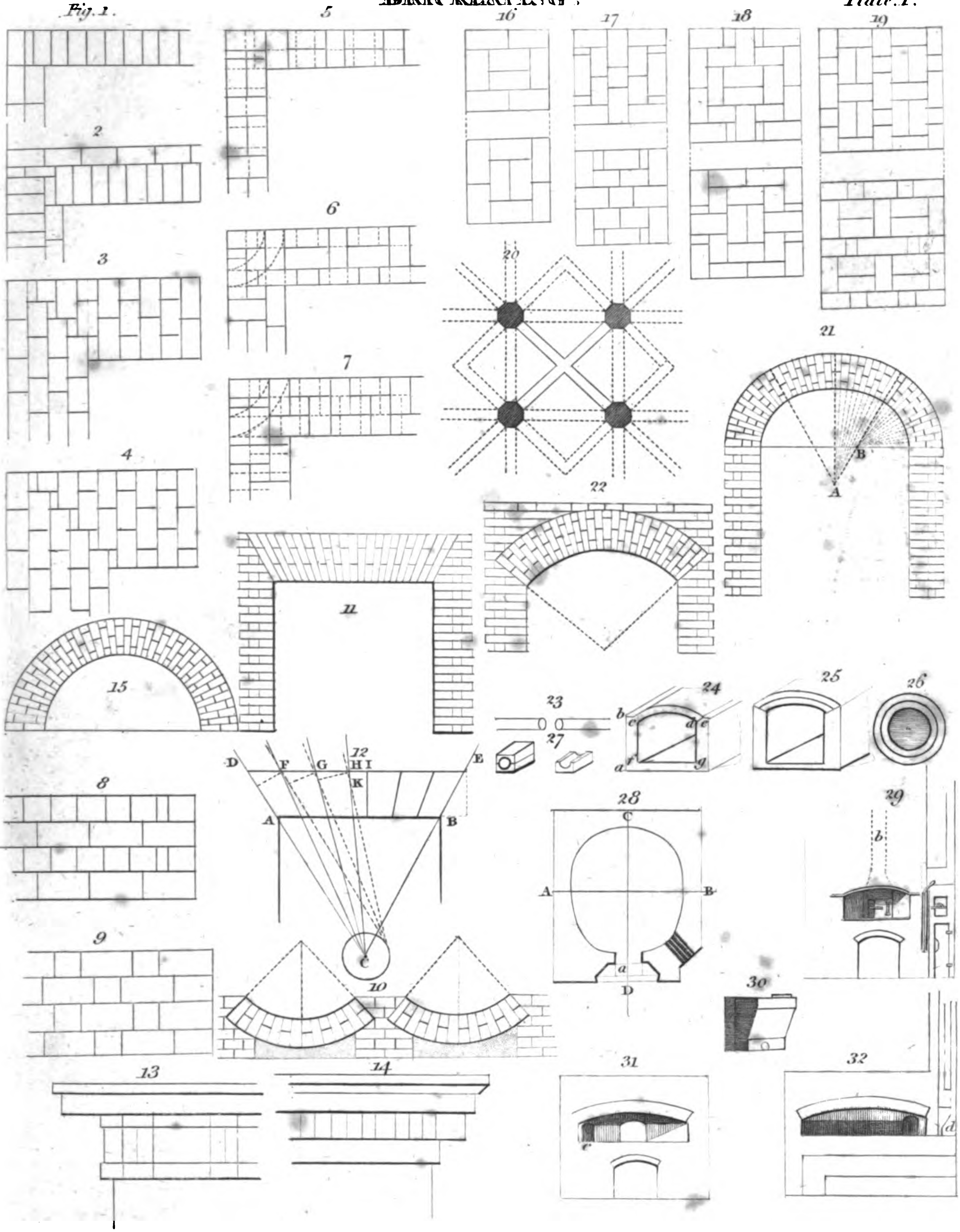
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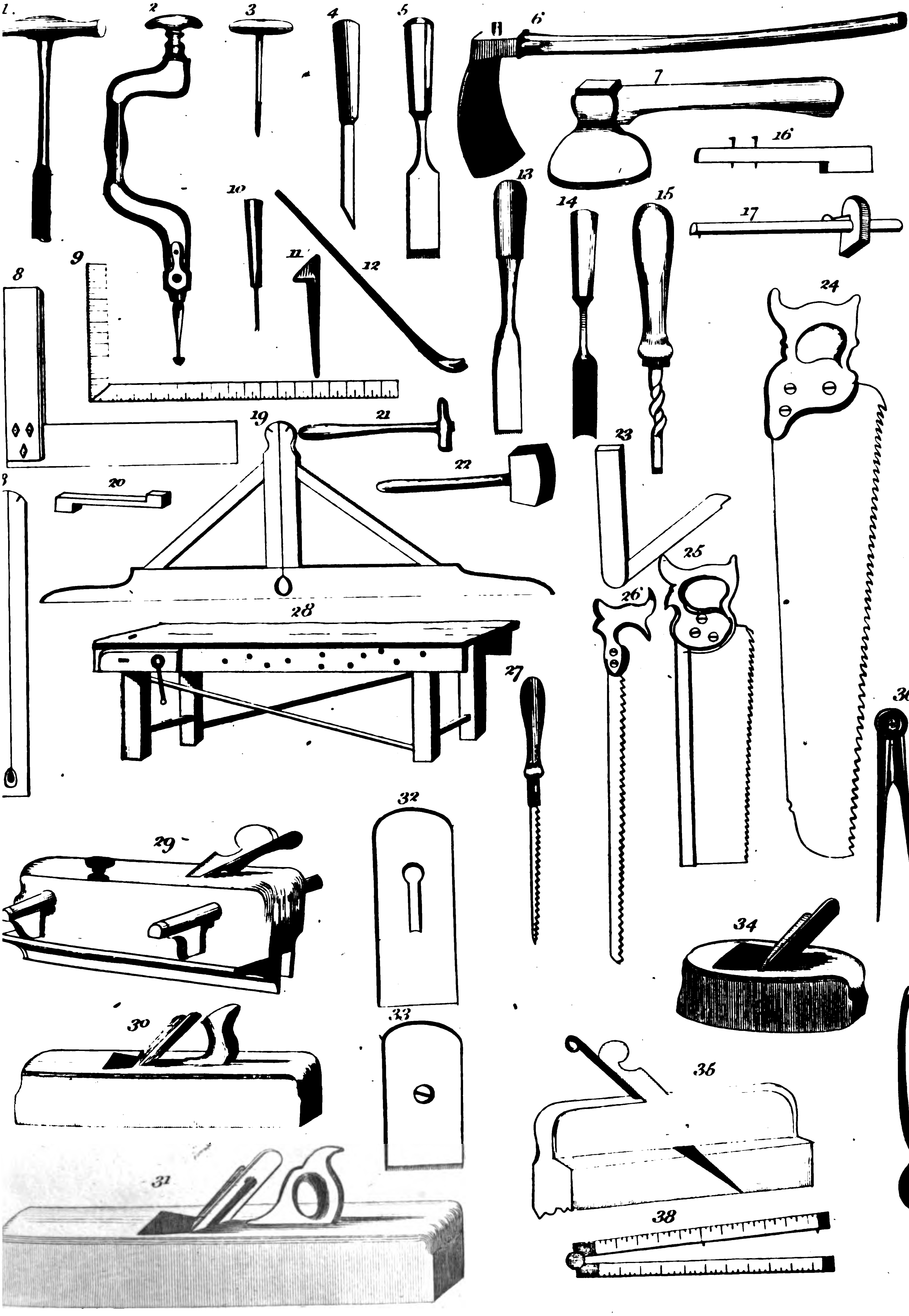
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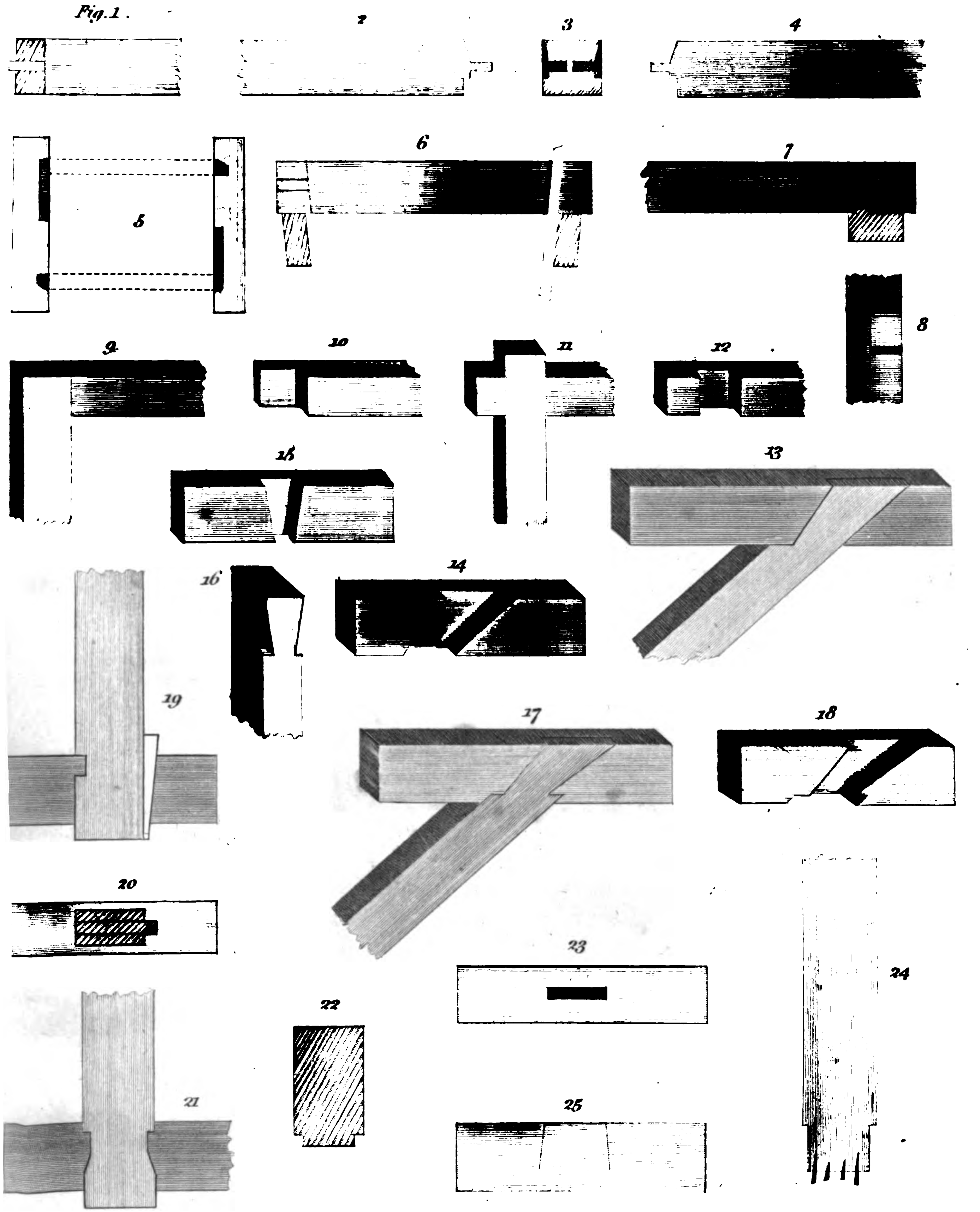
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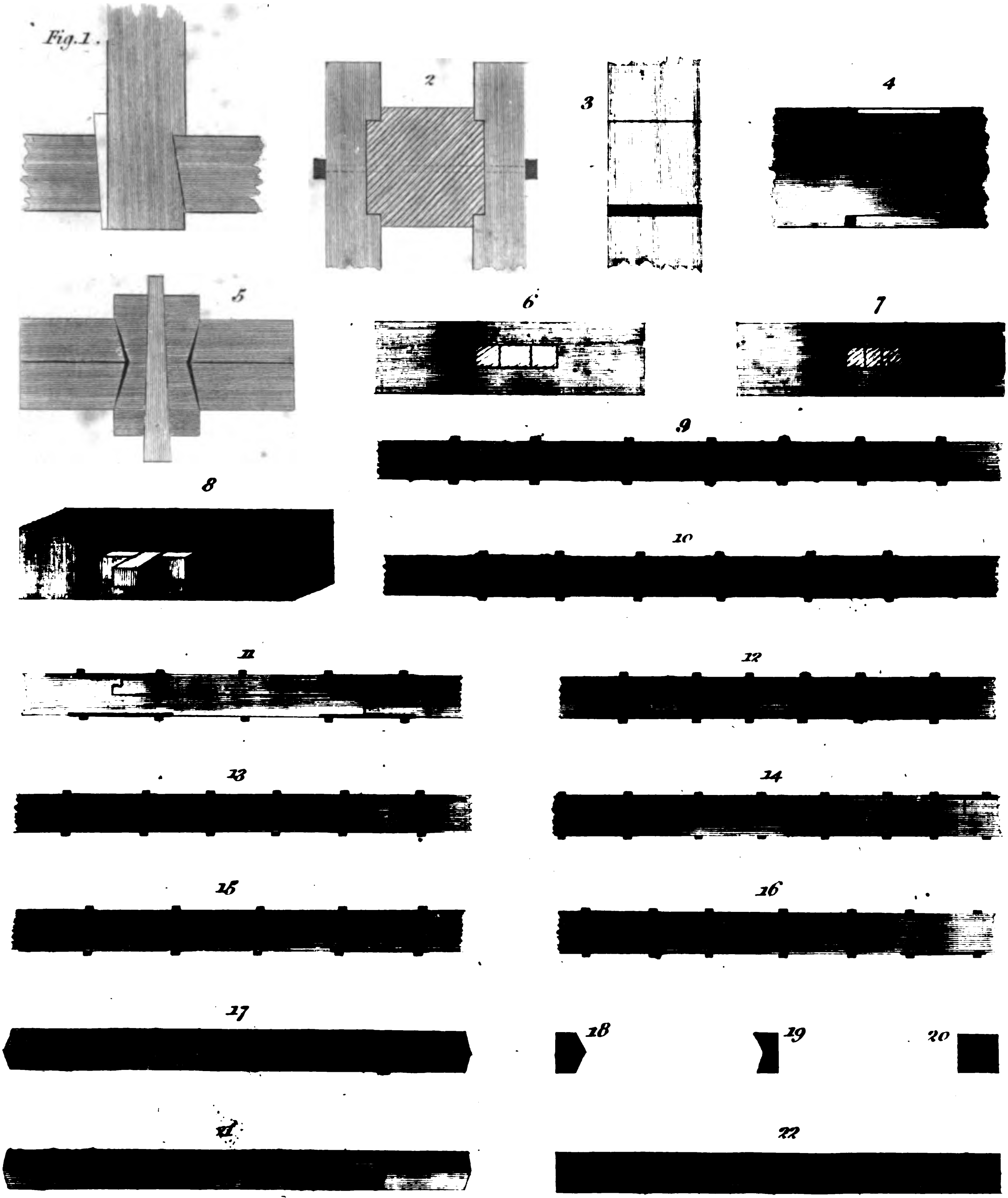
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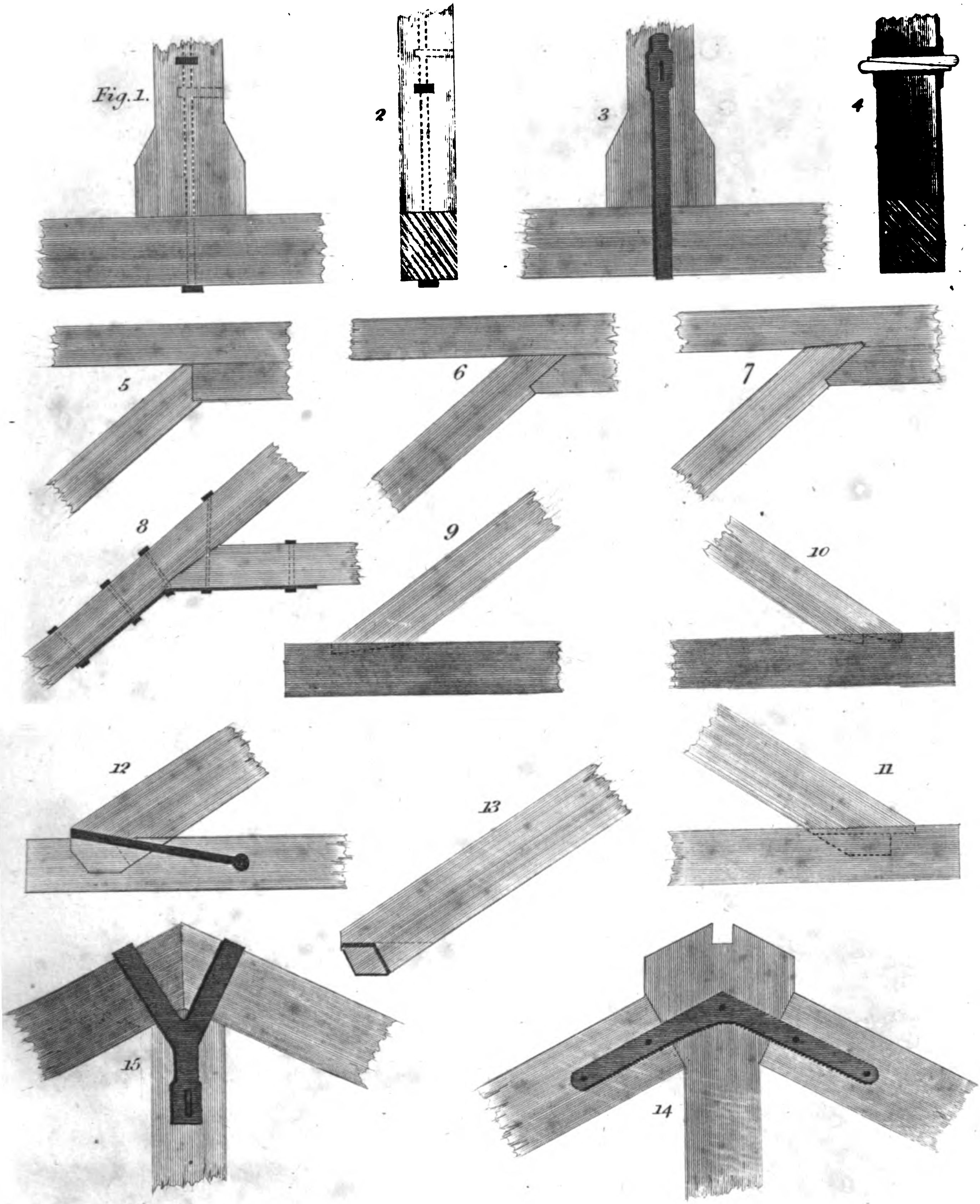
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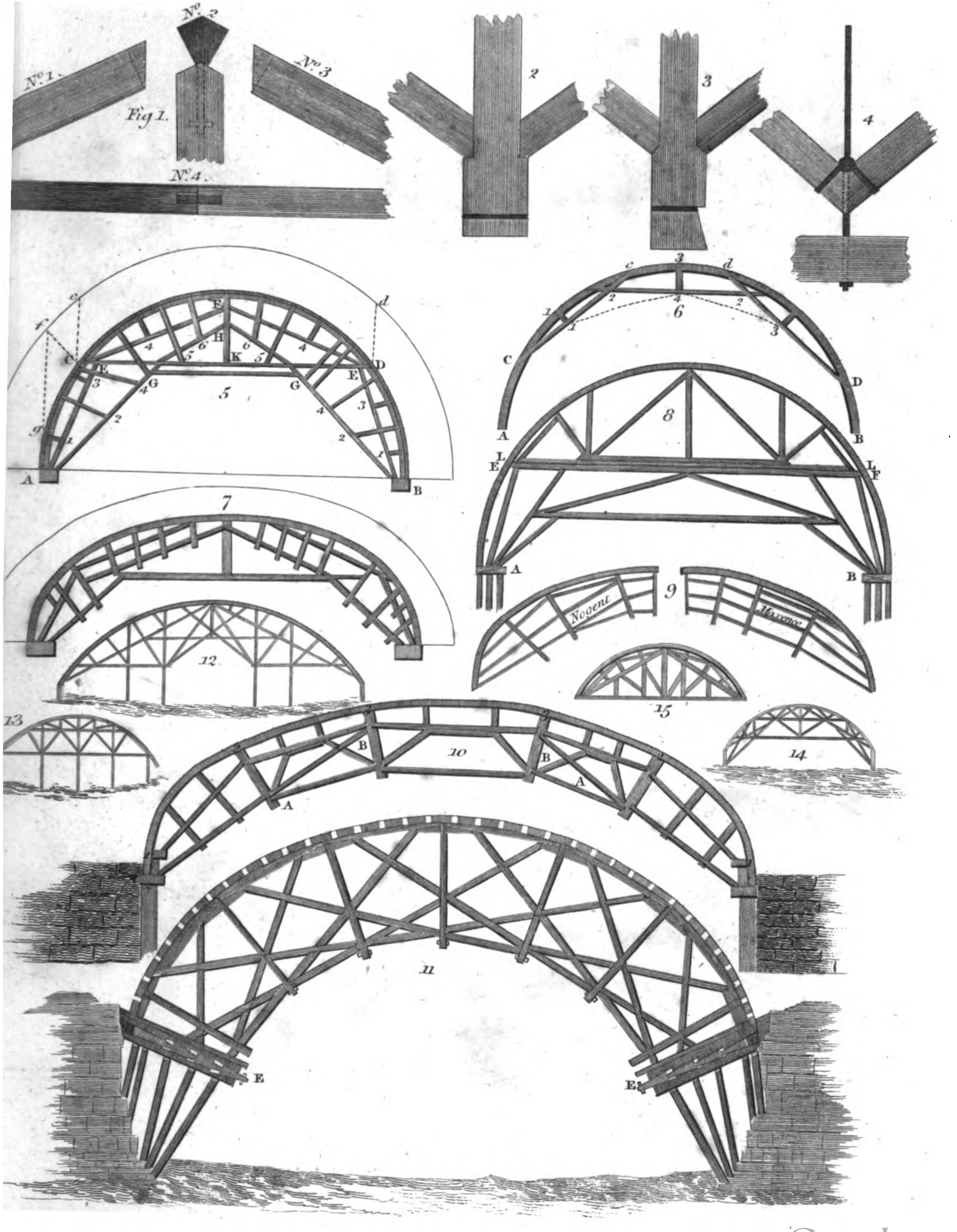
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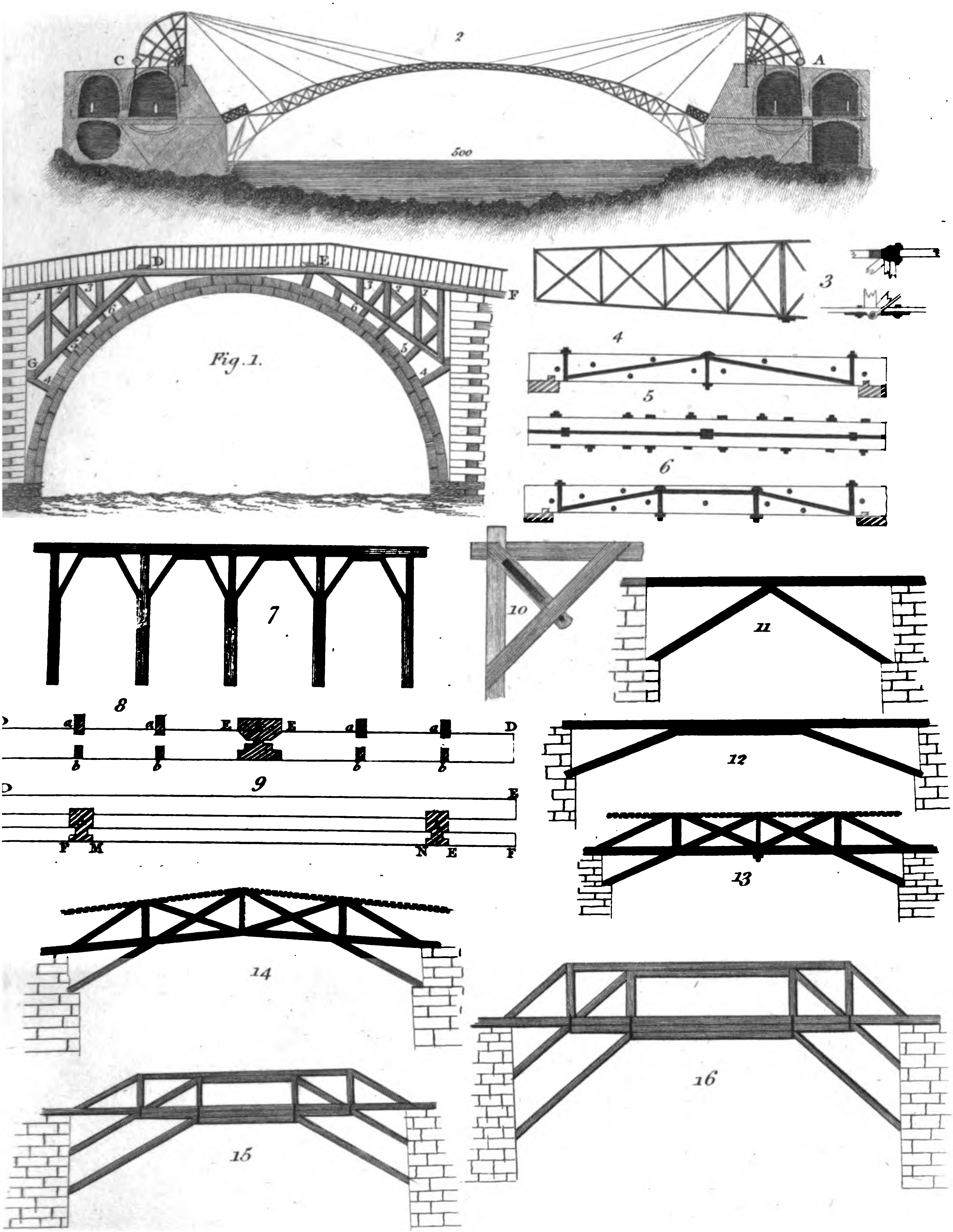
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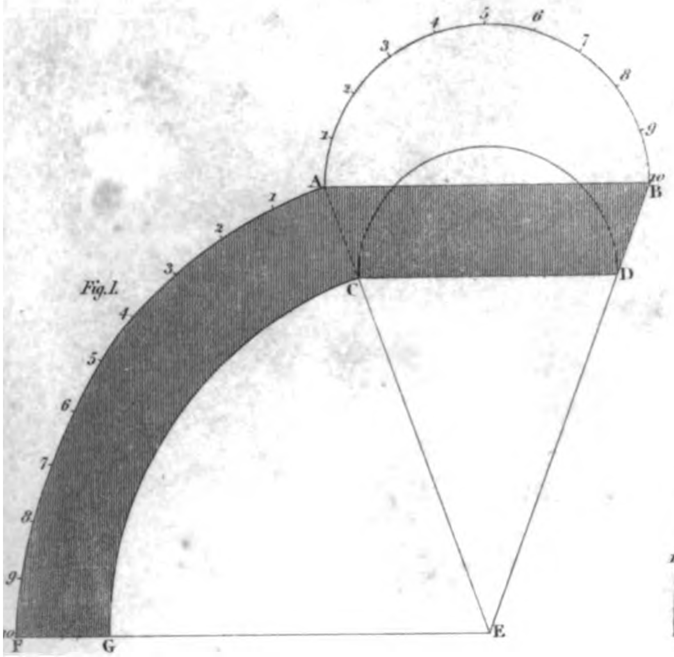

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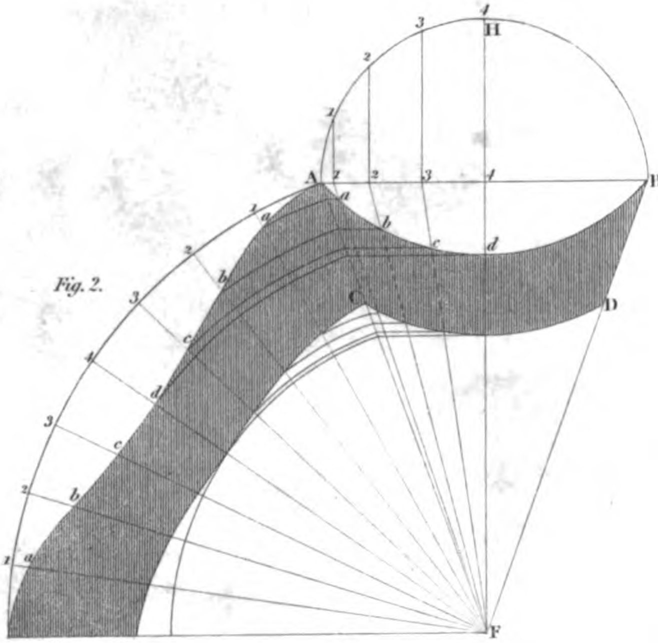

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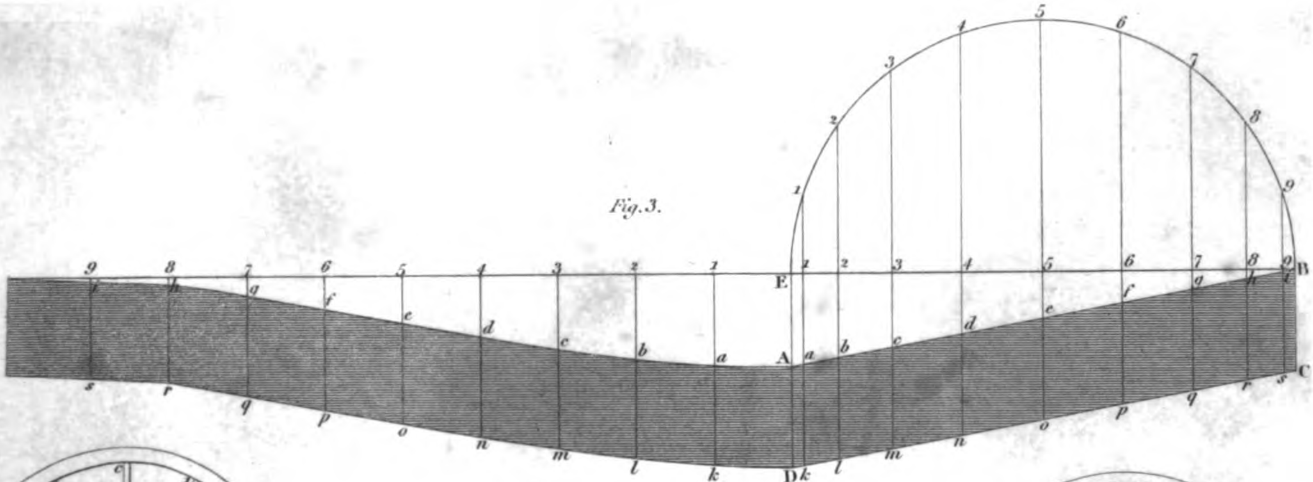

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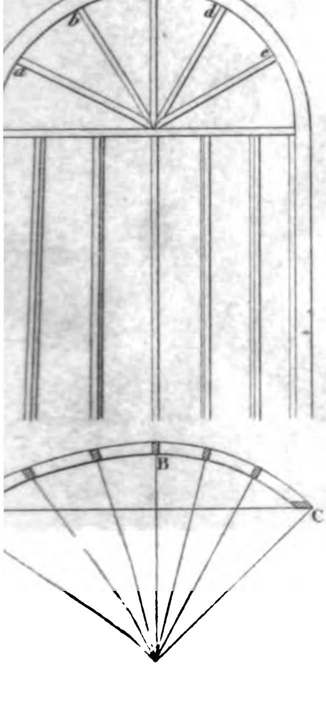

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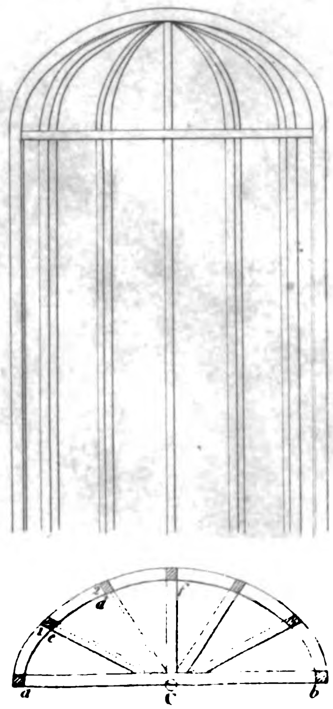

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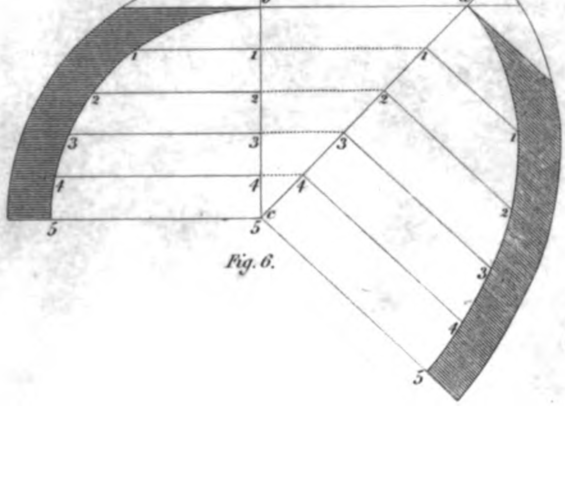

Fig. 6.

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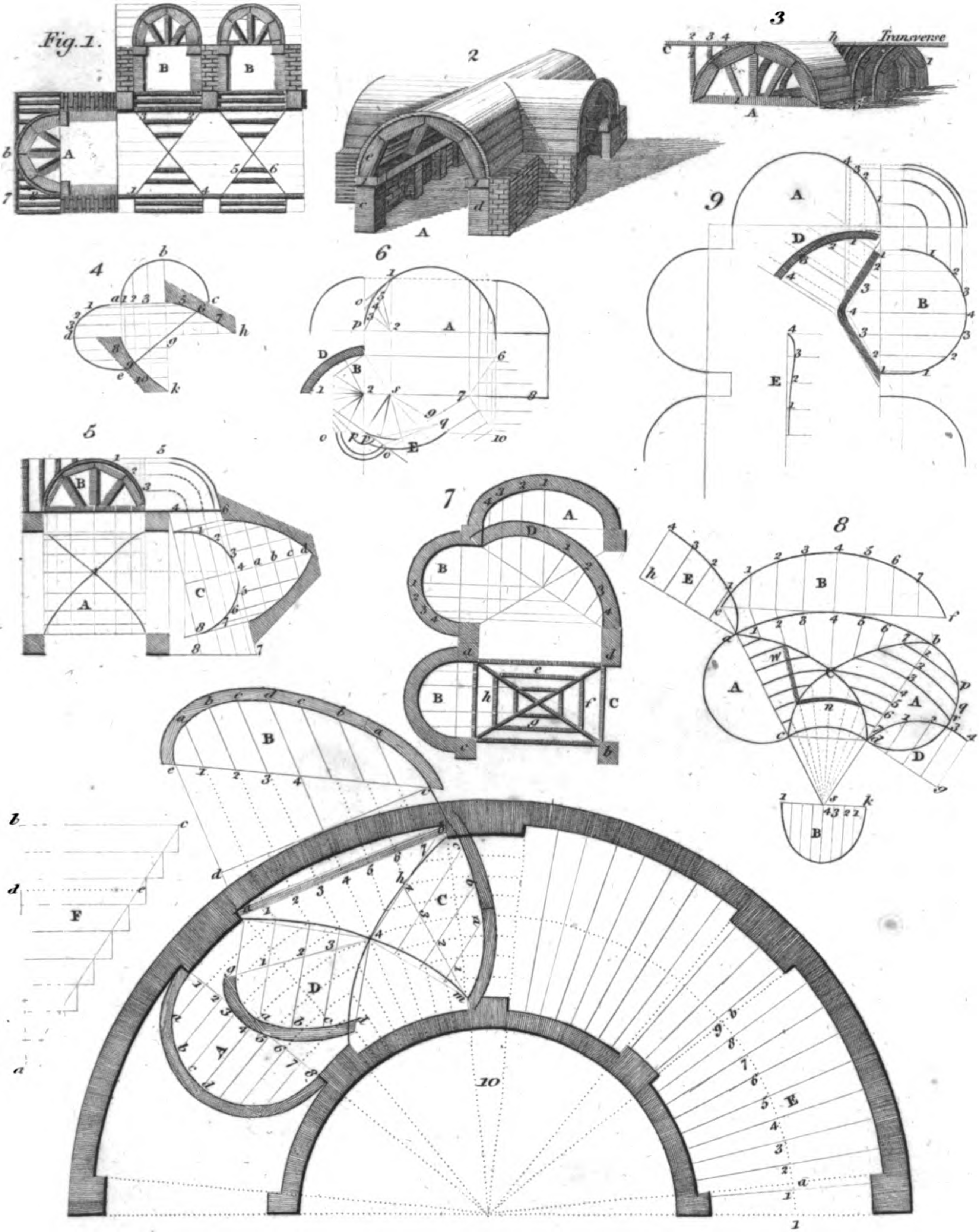
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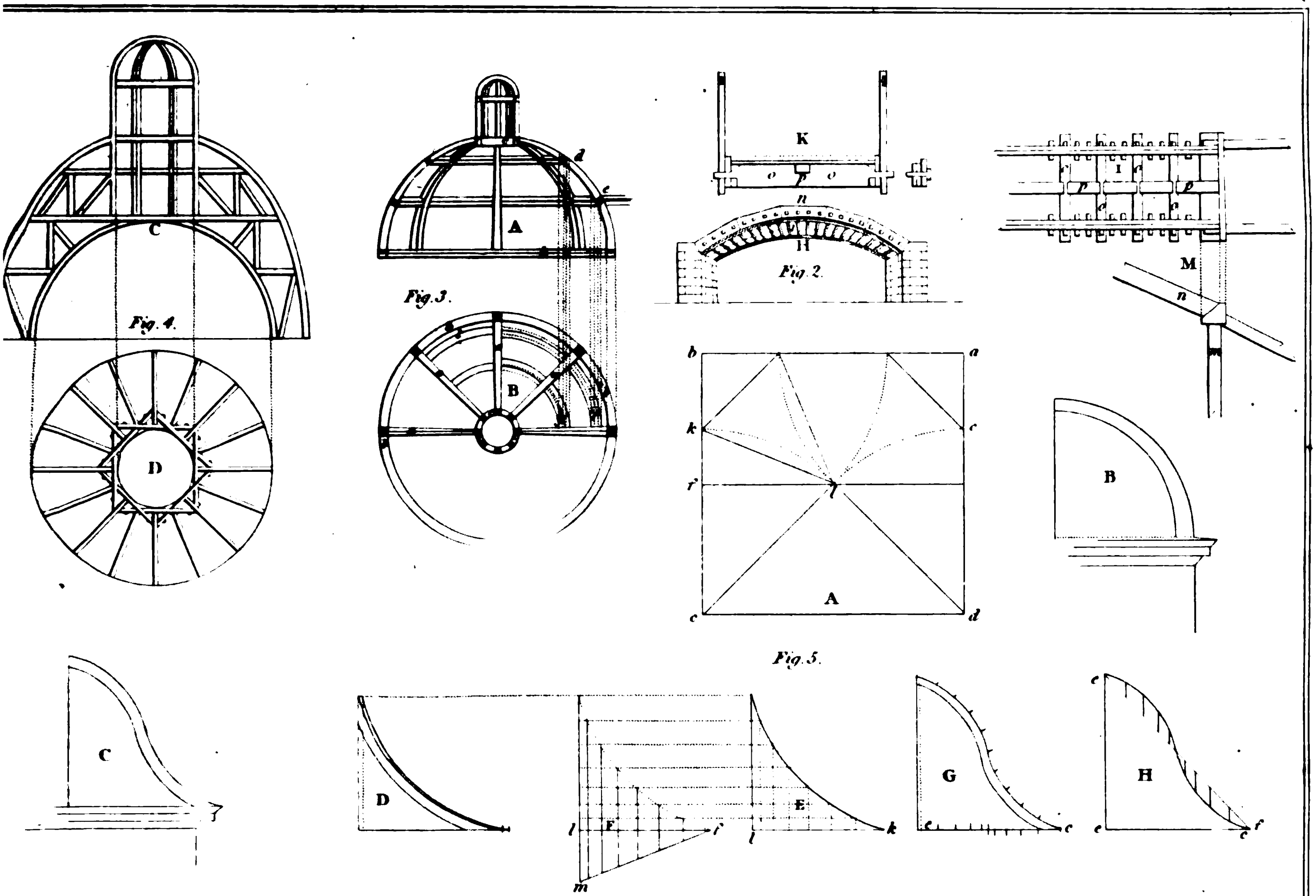
Plate 9.



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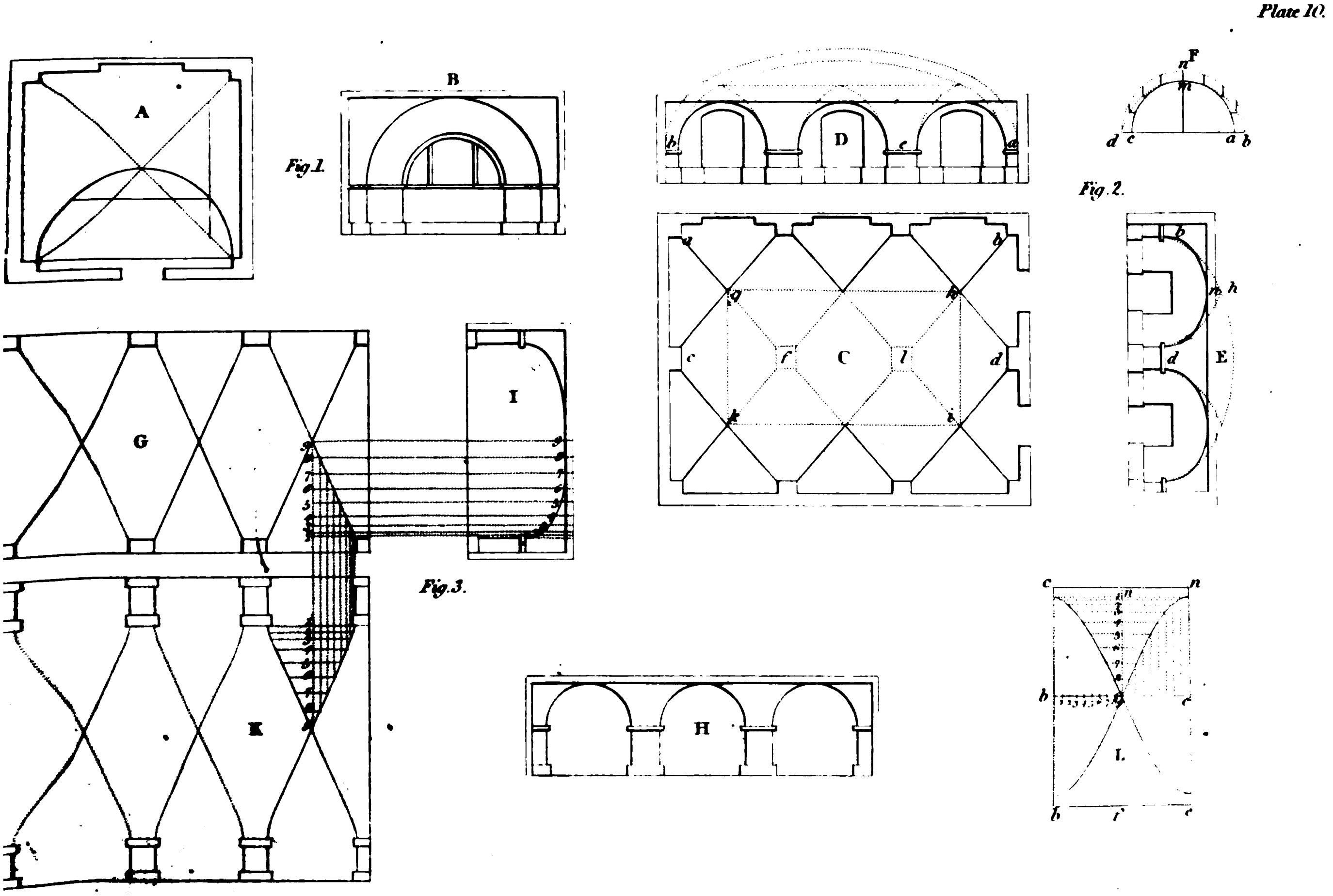

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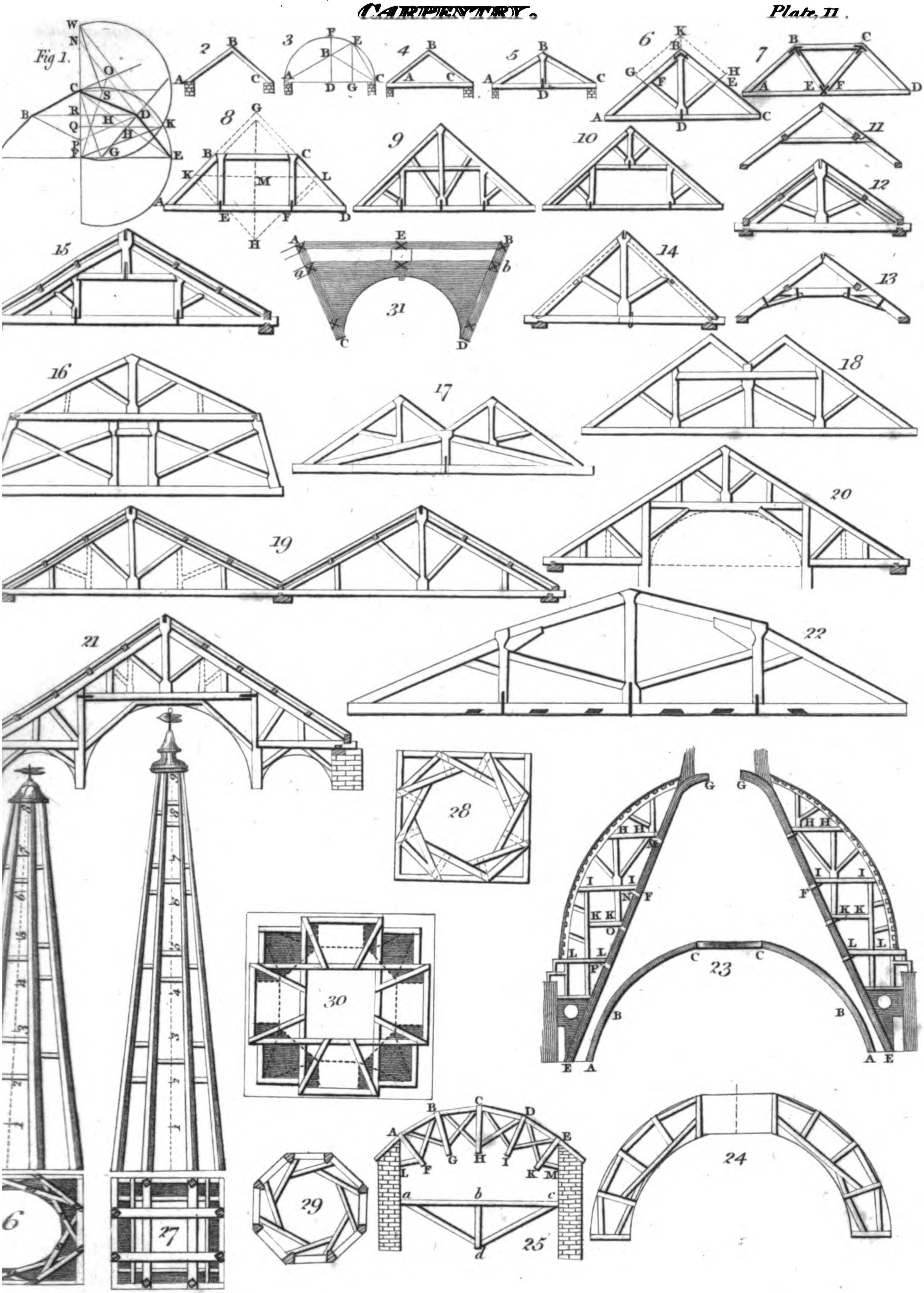

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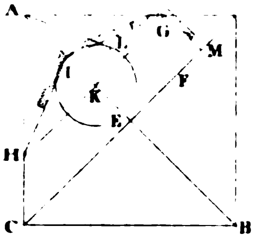

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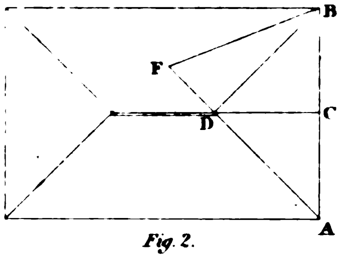

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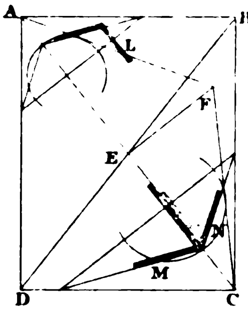

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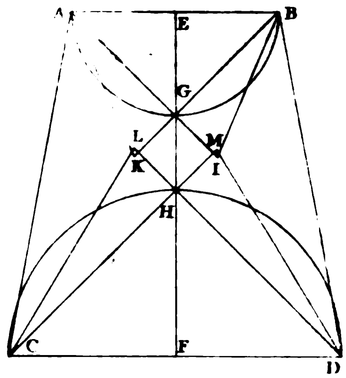

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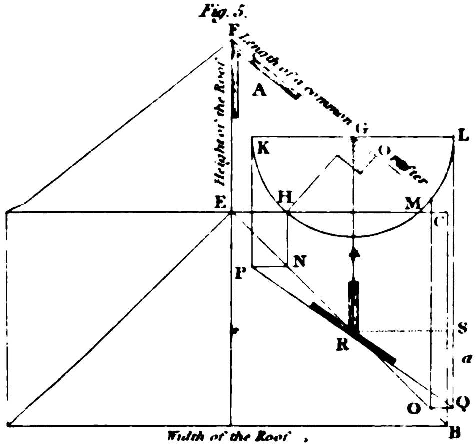

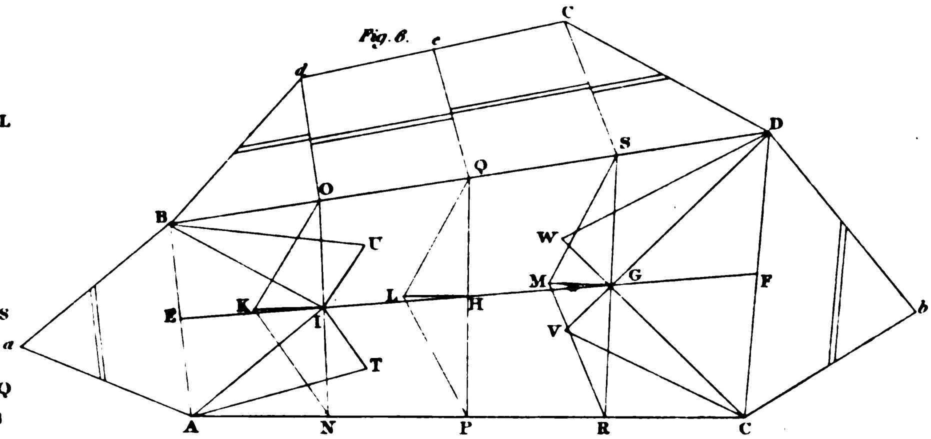

Fig. 6.

Plate 13.

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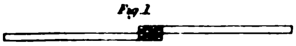

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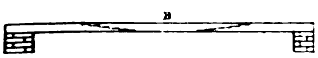
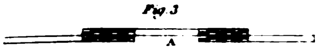


Fig. 3



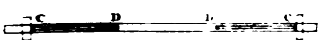
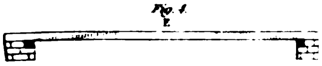


Fig. 4.



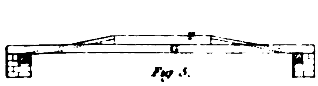


Fig. 5.

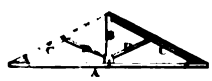


Fig. 8.

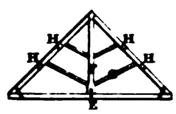


Fig. 9.

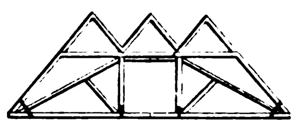


Fig. 10.

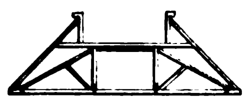
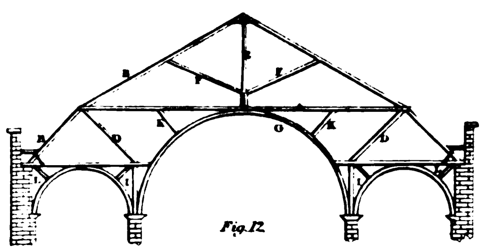


Fig. 11.



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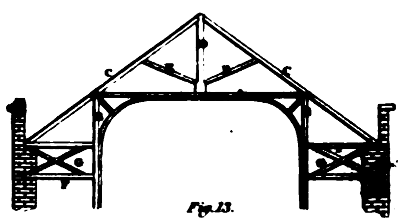

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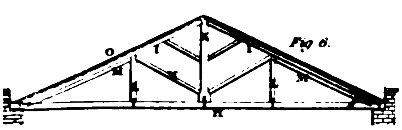


Fig. 6.

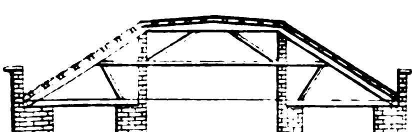


Fig. 7.

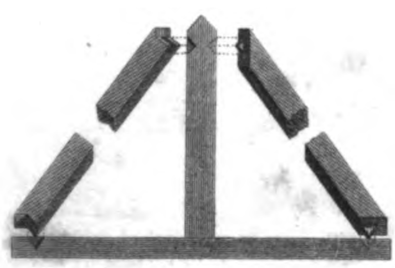


Fig. 14.

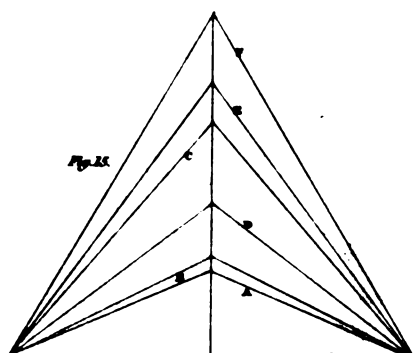


Fig. 15.

London Published 1813 by Gale Curtis & Fenner; and Rees & Curtis Plymouth.

CARPENTRY

Plate 14.

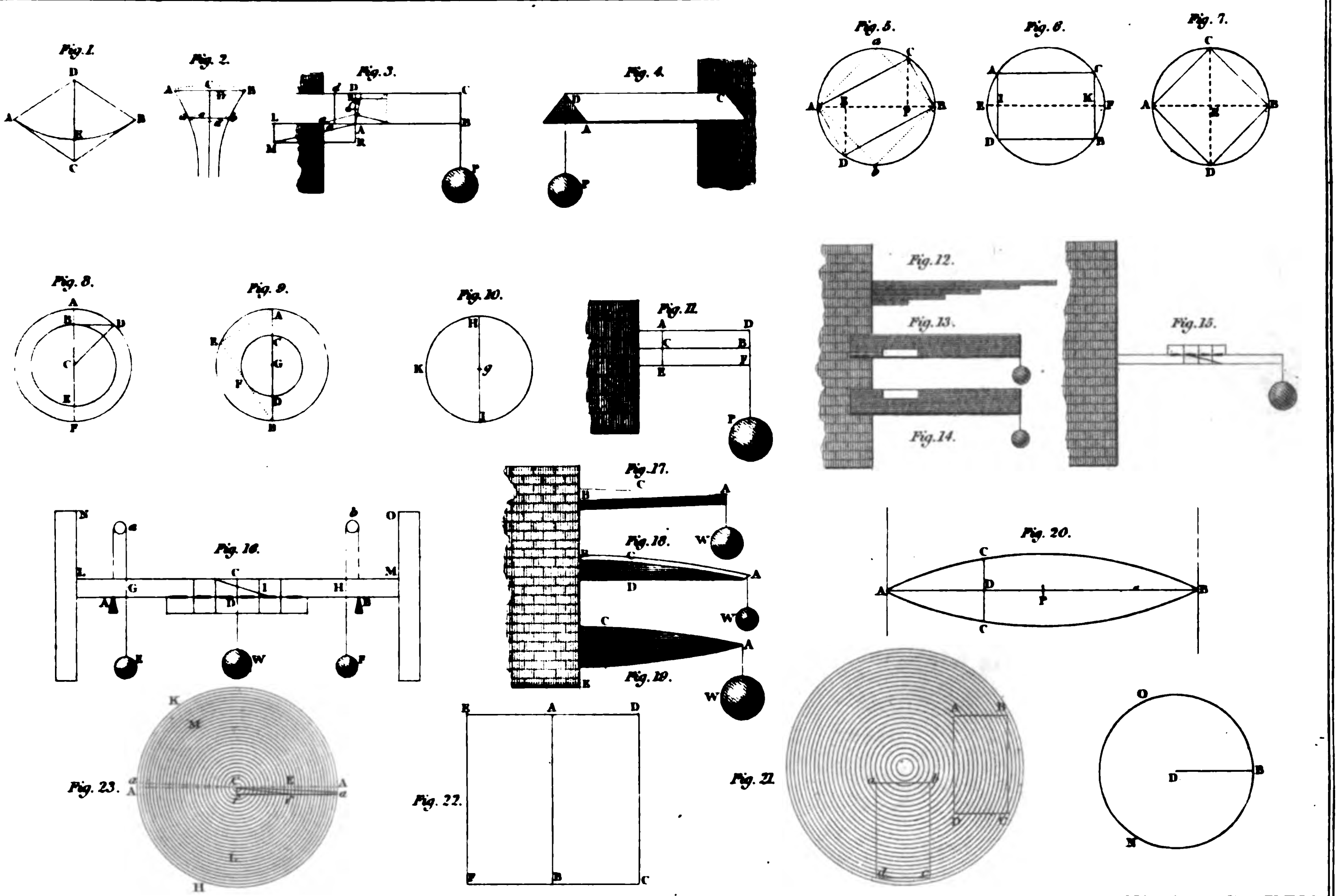
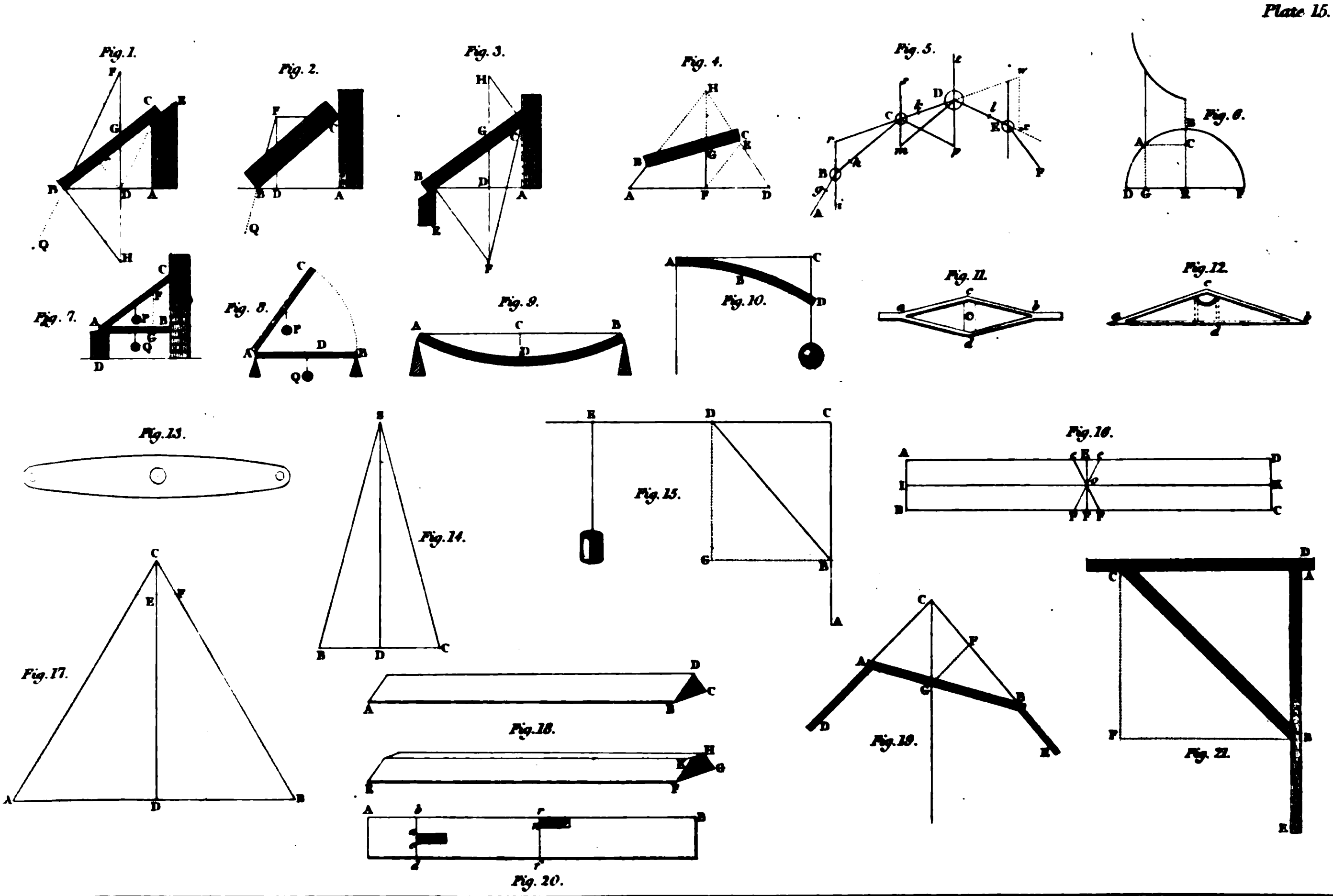


Plate 15.



Harvey jun.r del.t

London, Published 1813, by Gale, Curtis, & Fenner and Rees, & Curtis, Plymouth.

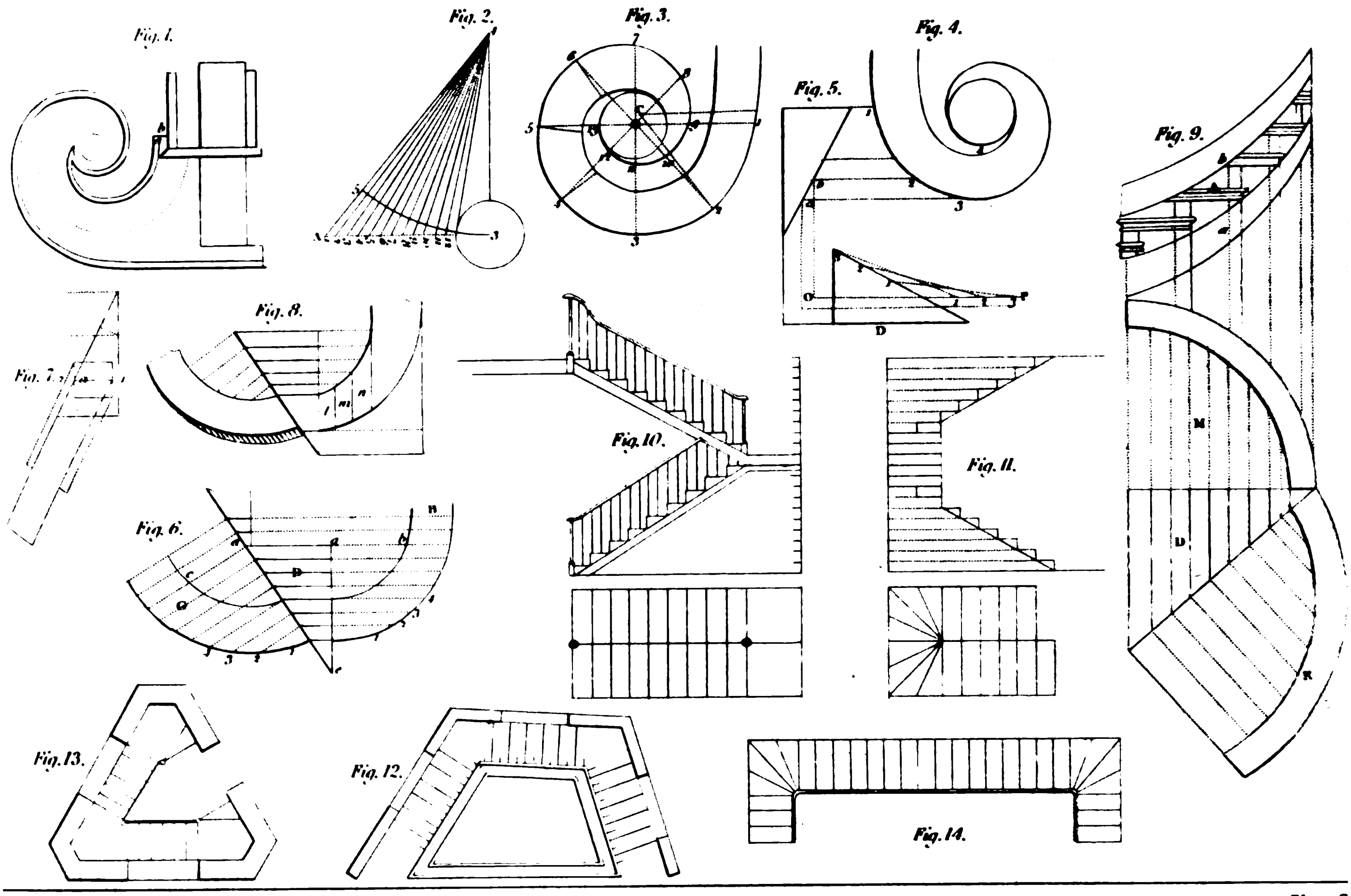
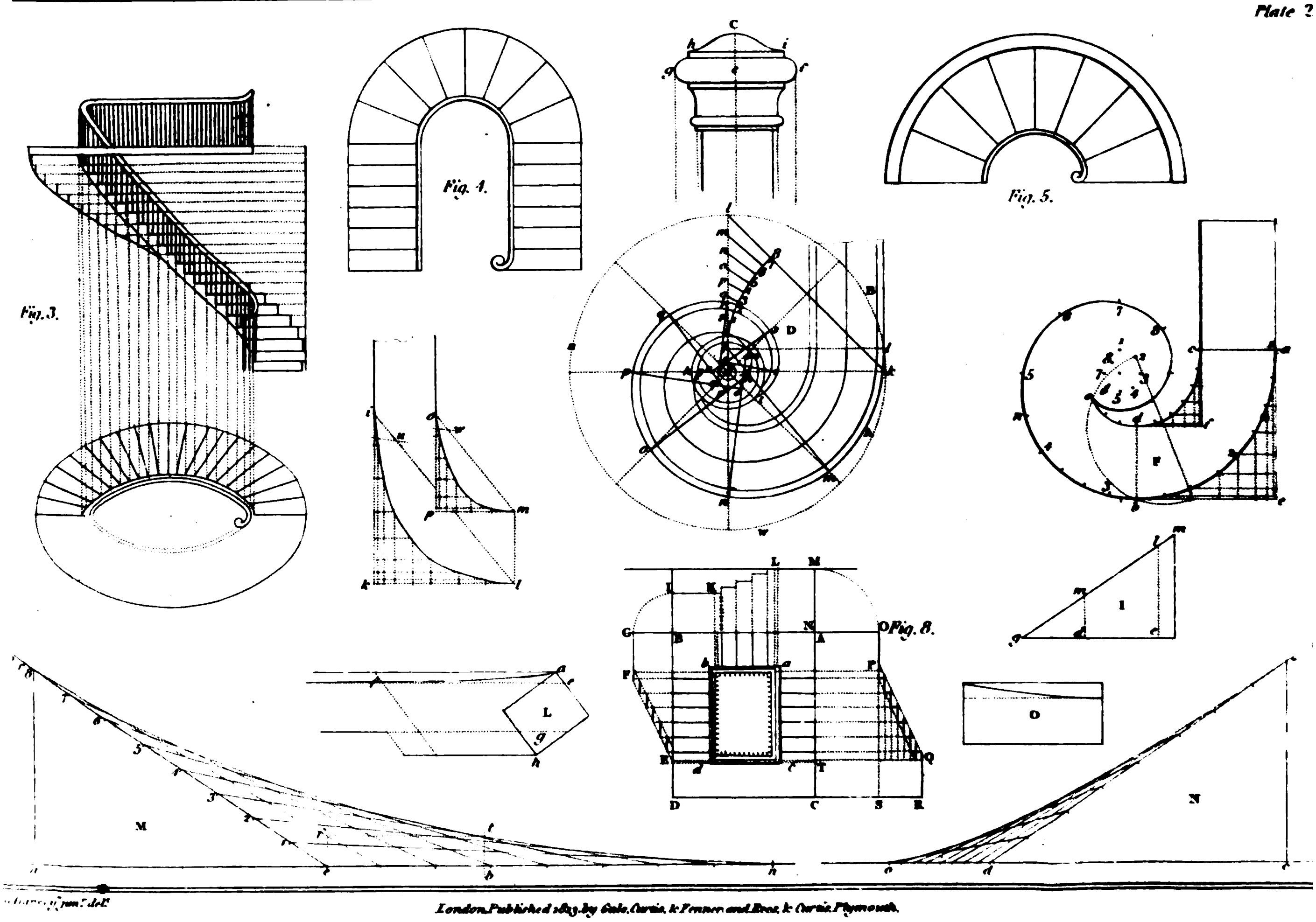


Plate 2



del.

London, Published 1823, by Gale, Curtis, & Fenner and Rees, & Curtis, Plymouth.

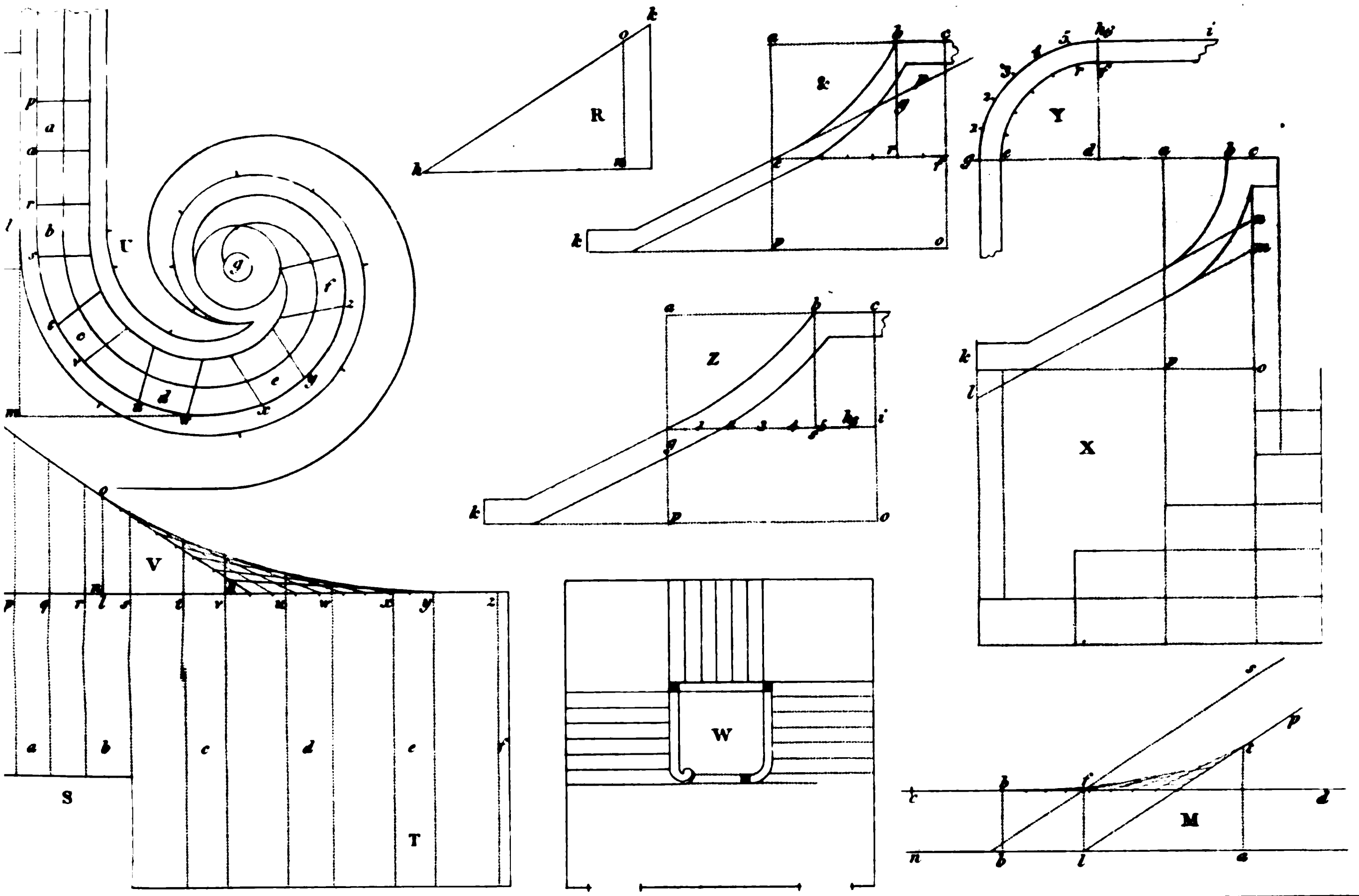
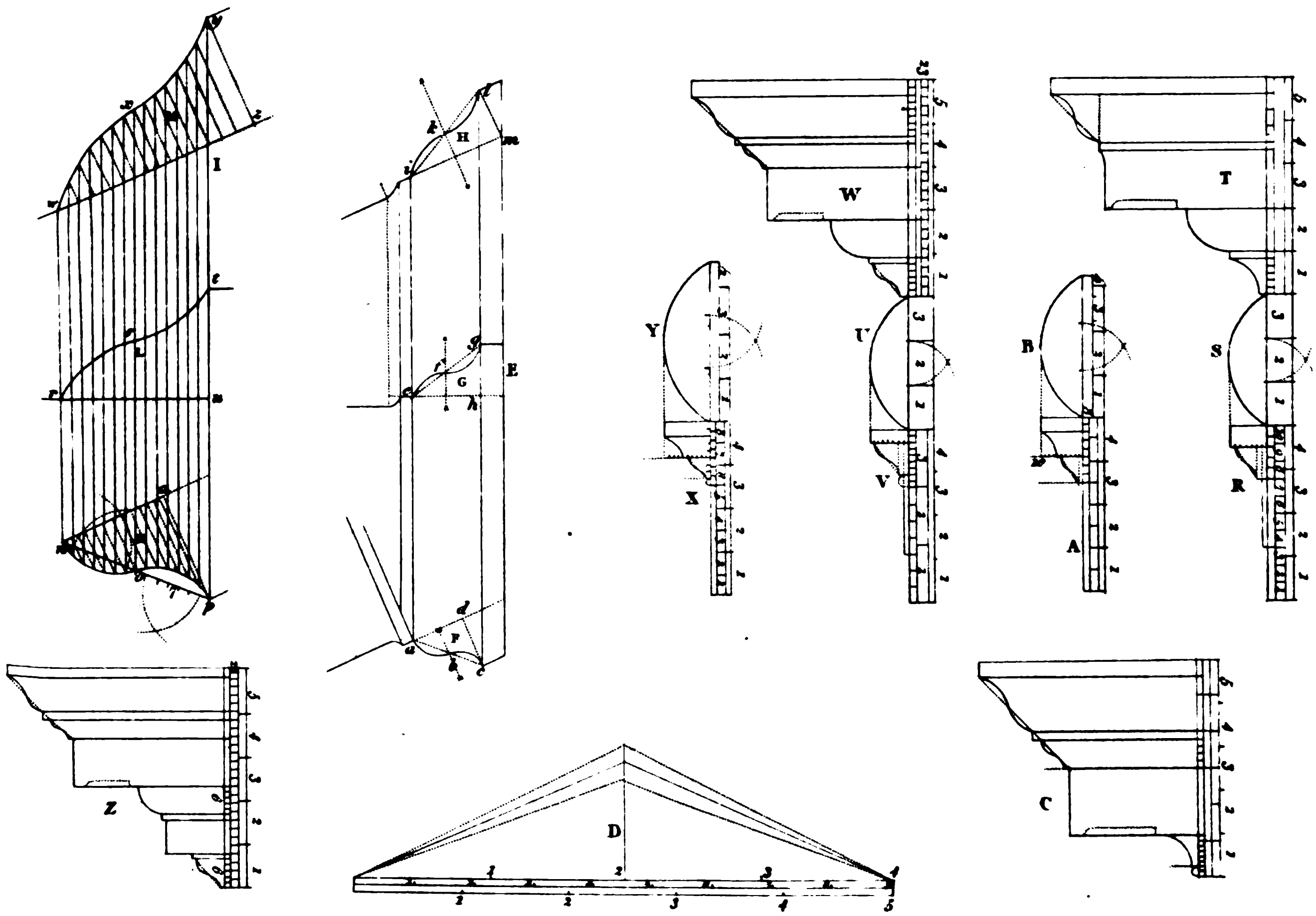


Plate 4.

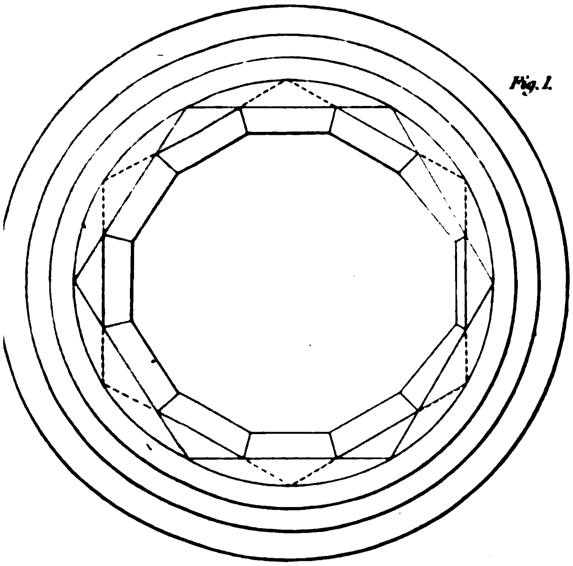


... cy jun.r del.t

London, Published 1813 by Gale, Curtis & Fenner and Rees & Curtis Plymouth.

JOINERY

Fig. 1.



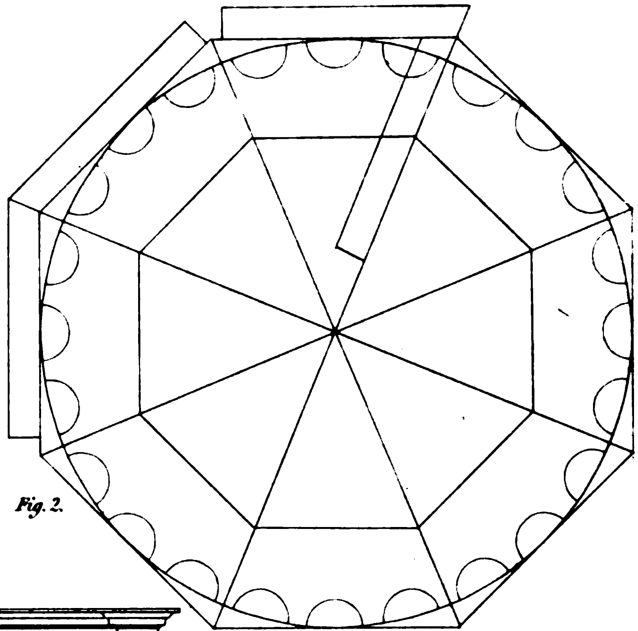


Fig. 2.

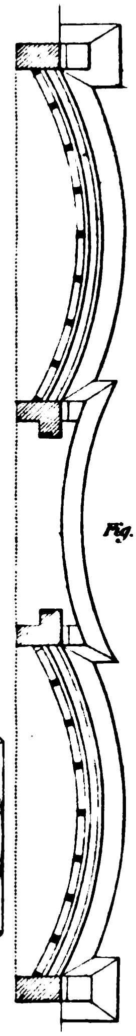


Fig. 6.

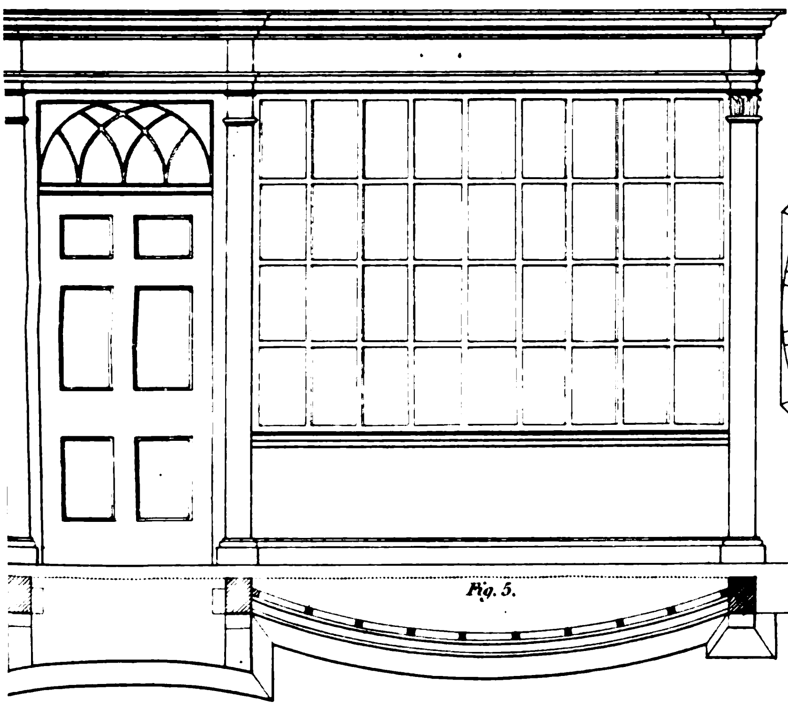


Fig. 5.

Fig. 3.

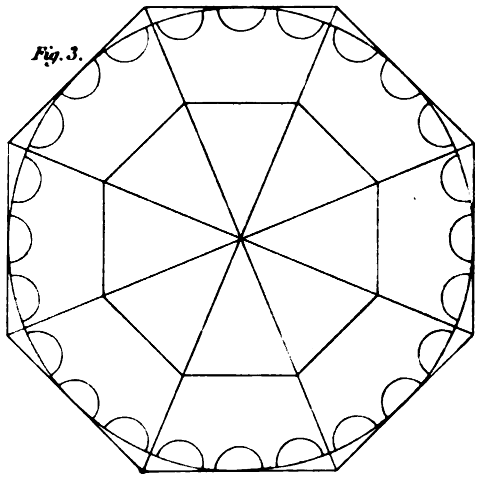
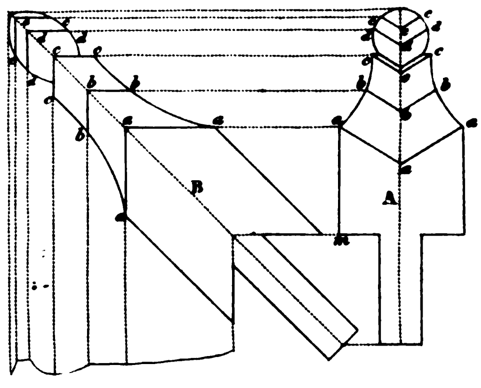


Fig. 9.



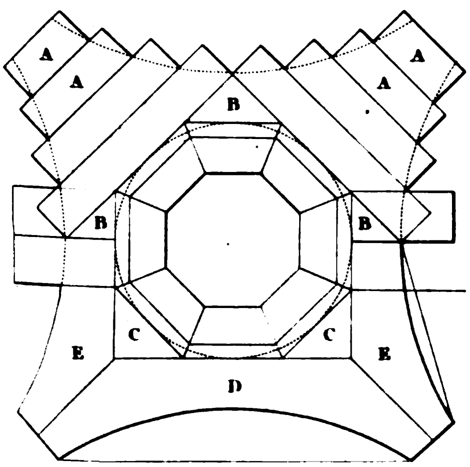
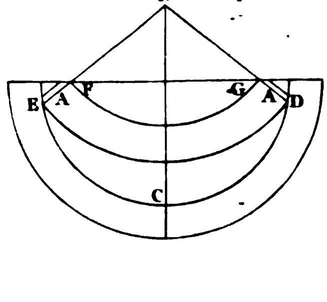


Fig. 4.

Fig. 7.



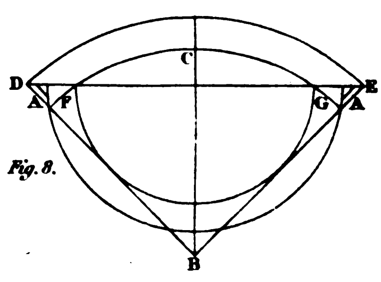
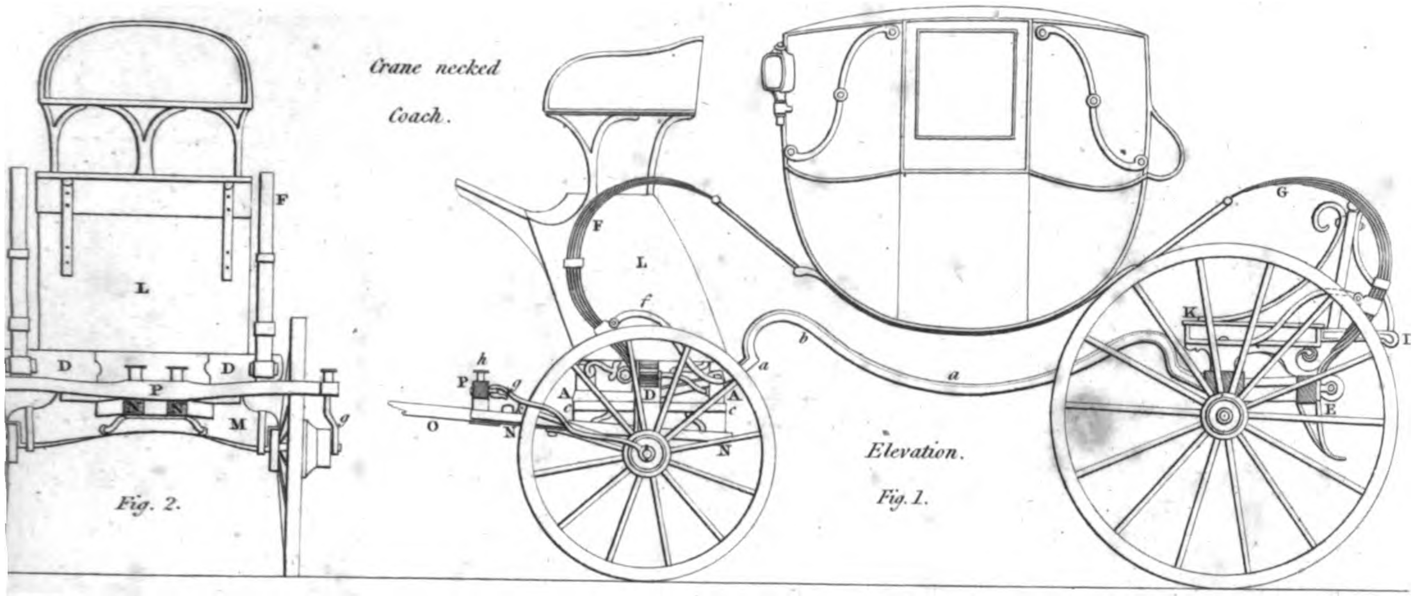


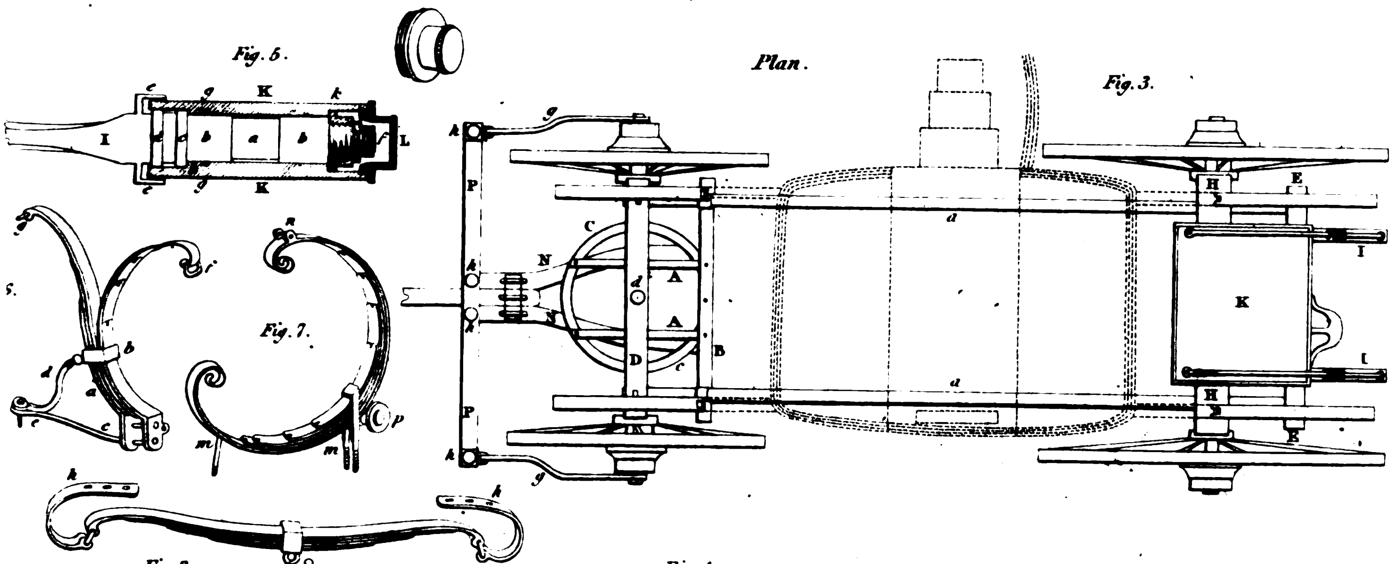
Fig. 8.

...y, jun. del.

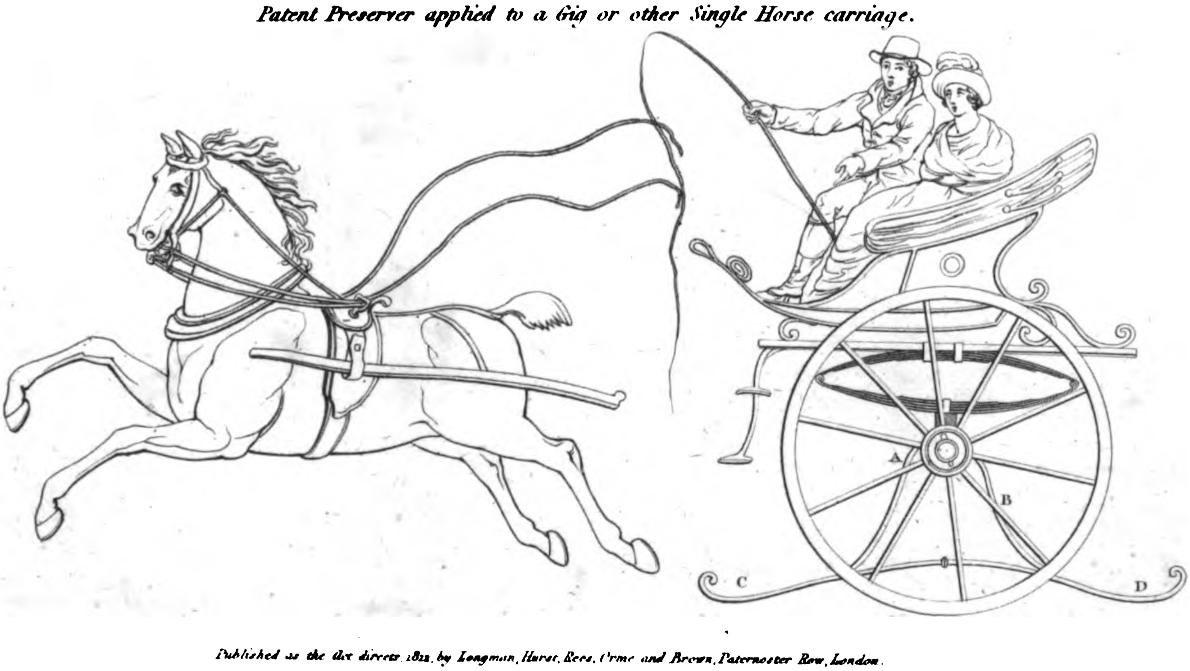
London, Published 18[illegible], by Gale, Curtis, & Fenner, & Rees & Curtis, Plymouth.

Front View.





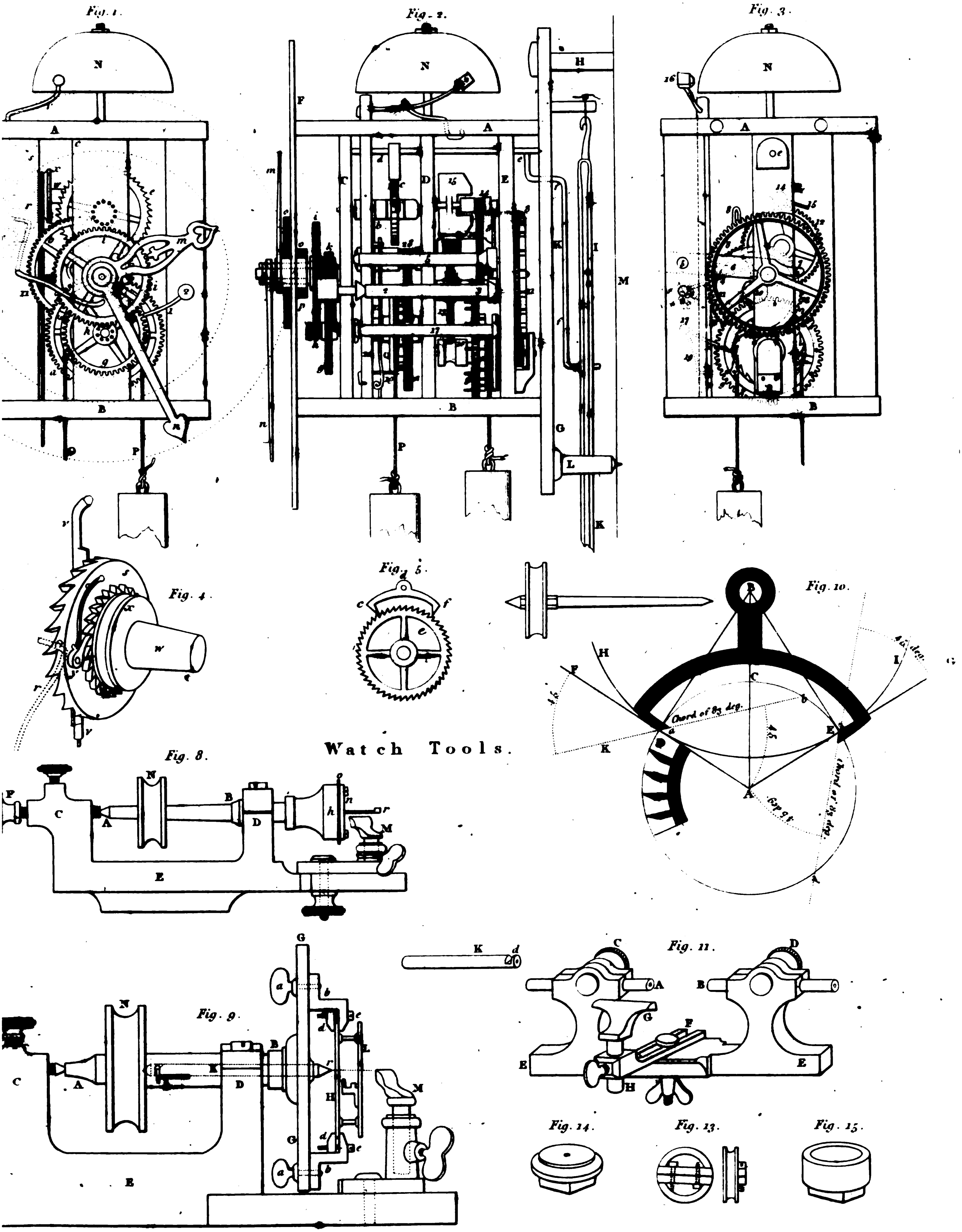
Patent Preserver applied to a Gig or other Single Horse carriage.



Published as the Act directs 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Lowry sculp.

CLOCK WORK

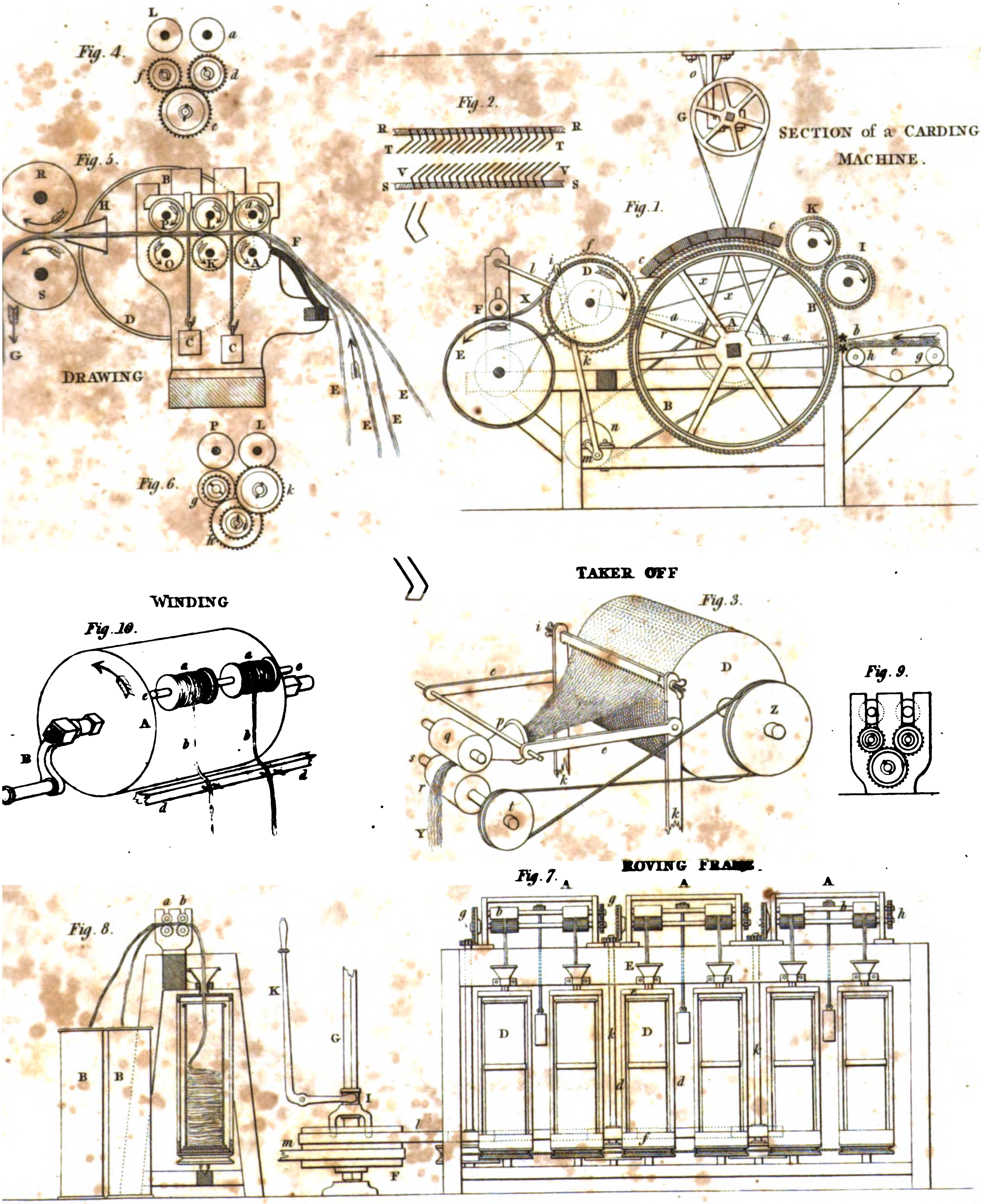


Watch Tools.

'elin.

Published for Gale & Curtis London, & Rees & Curtis Plymouth July 13, 1812.

COTTON MACHINERY.



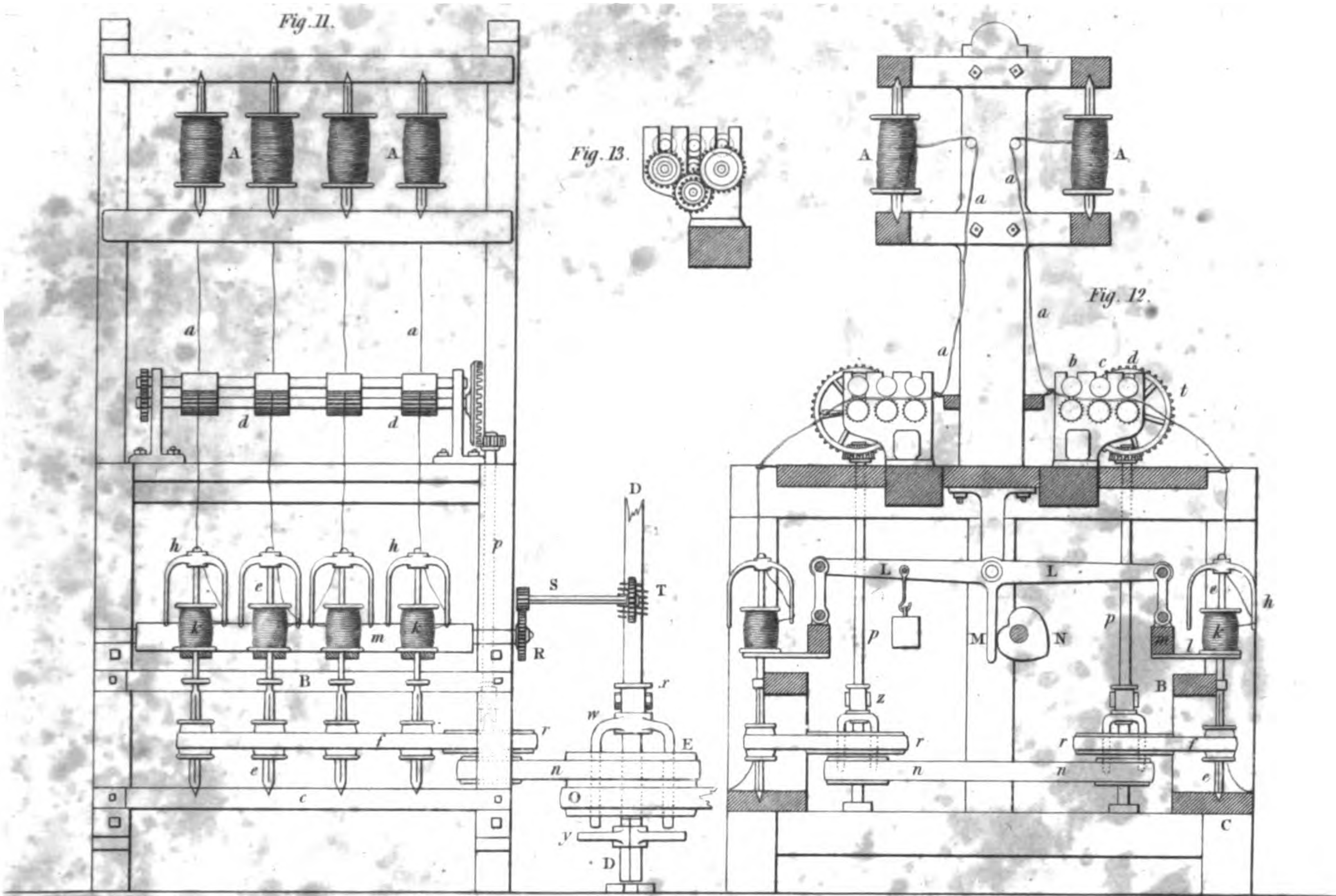
Farey, delin.

Lowry, sculp.

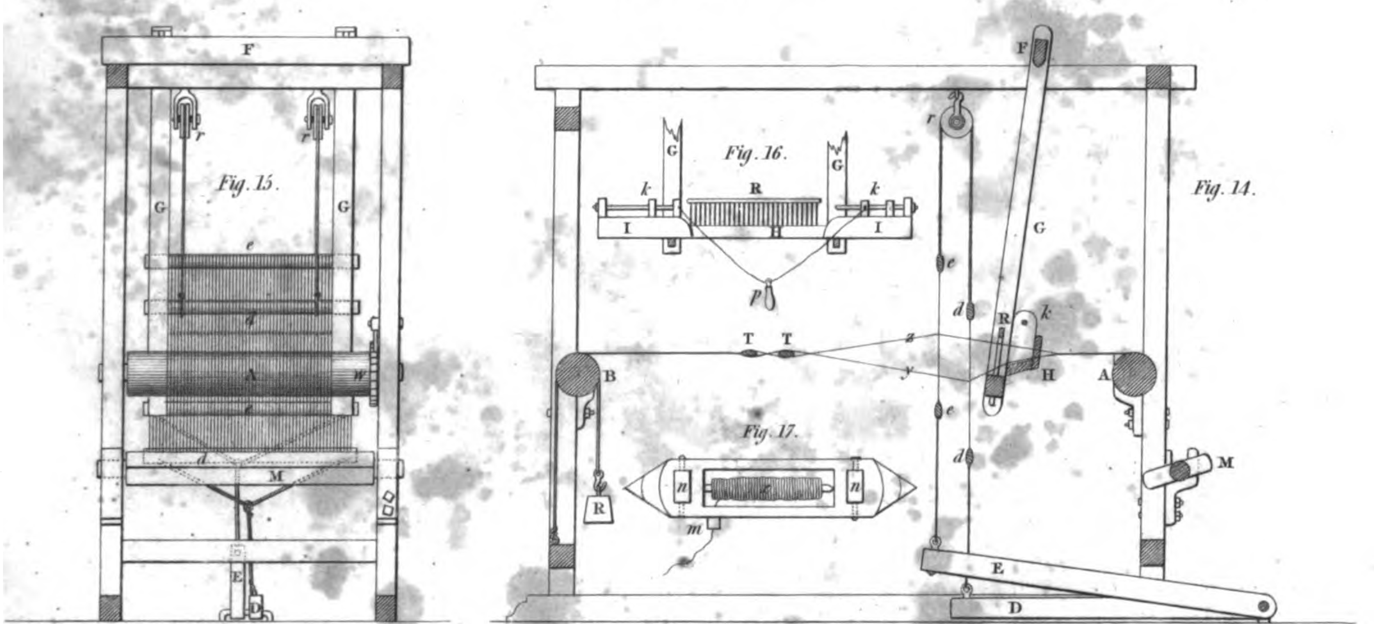
London. Published by Gale, Curtis & Fenner. & Rees & Curtis, Plymouth, 181[illegible].

COTTON MANUFACTURE.

SPINNING.



WEAVING.



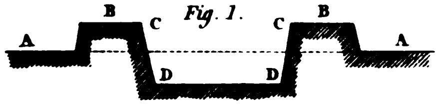
J. Farey. delin. Lowry. sculp.

London, Published by Gale, Curtis & Fenner, & Rees & Curtis Plymouth, [illegible].

ENGINEERING.

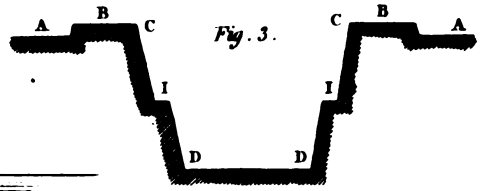
Level Cutting.

Fig. 1.



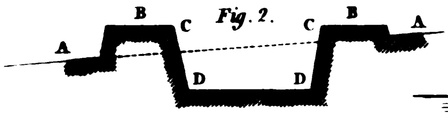
Deep Cutting.

Fig. 3.



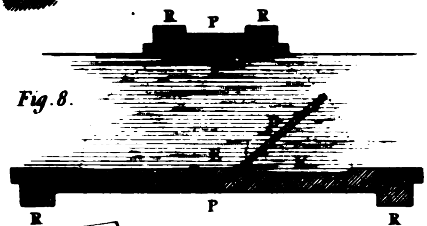
Side-lying Cutting.

Fig. 2.



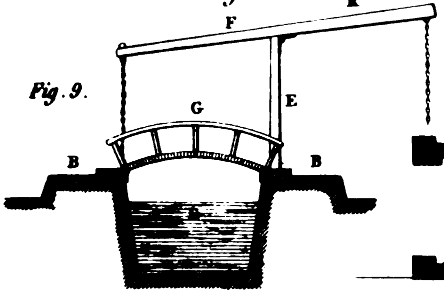
Safety Gates.

Fig. 8.



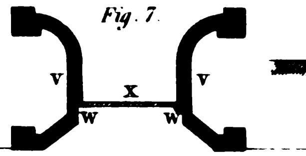
Draw Bridge.

Fig. 9.



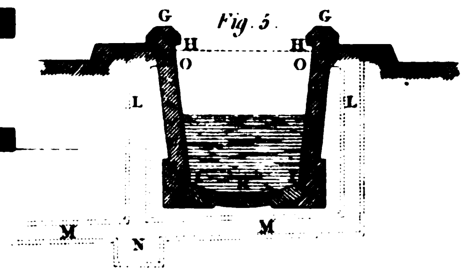
Waste Gates.

Fig. 7.



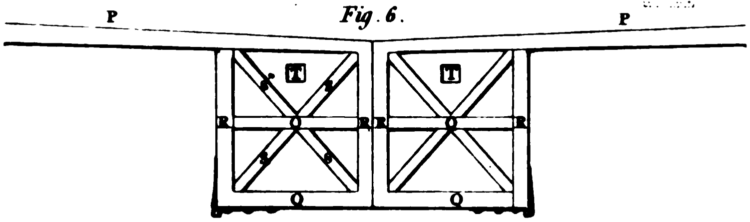
Section of a Lock

Fig. 5.

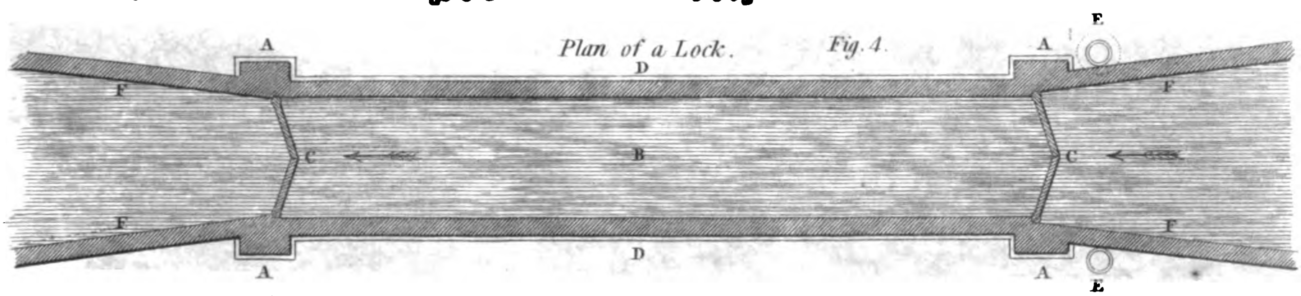


Lock Gates.

Fig. 6.



Plan of a Lock. Fig. 4.

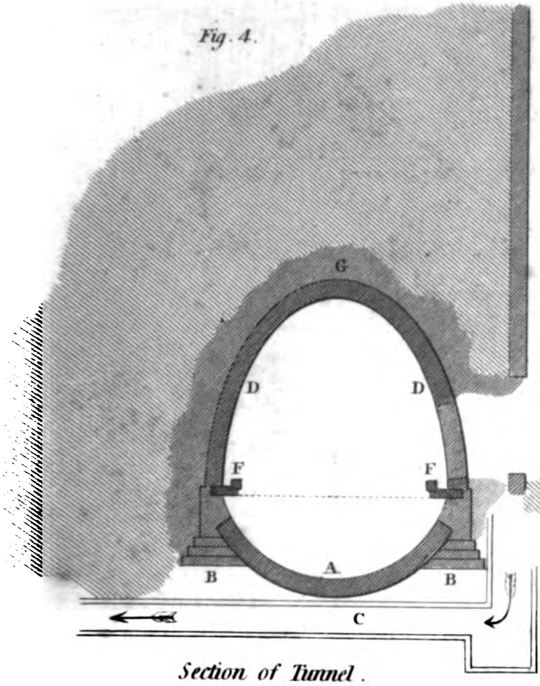


Lowry

London. Published by Gale, Curtis & Fenner, & Rees & Curtis, Plymouth 181·

ENGINEERING.

Fig. 4.



Section of Tunnel.

Fig. 7.

Fig. 8.

Iron Rail Road.

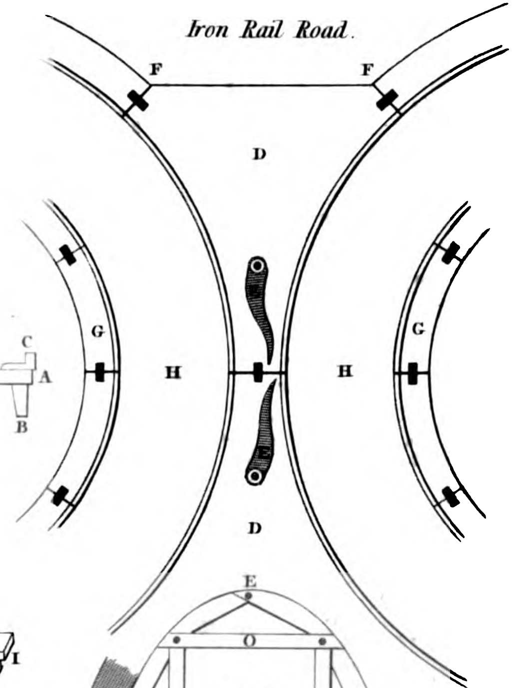


Fig. 9.

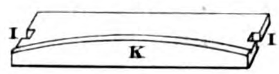
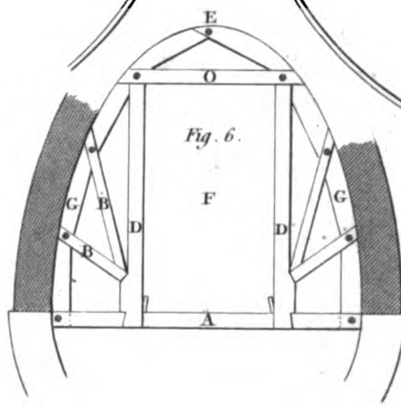
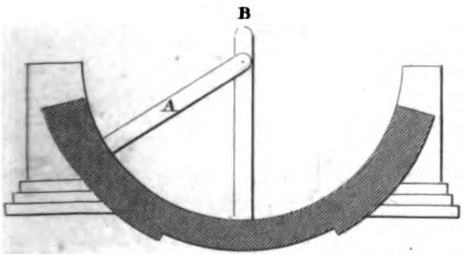


Fig. 6.



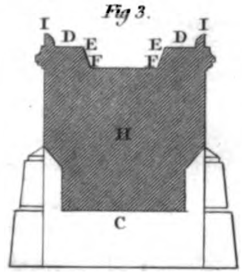
Centering to Soffit Arch.

Fig. 5.



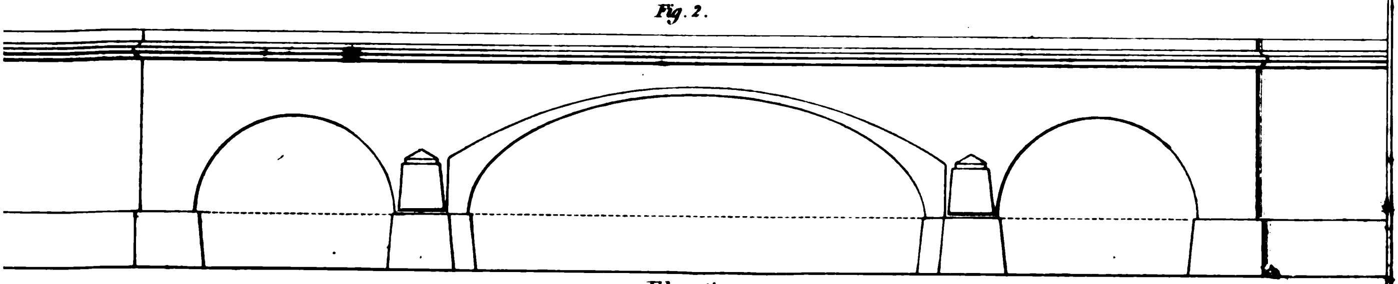
Inverted Arch.

Fig. 3.



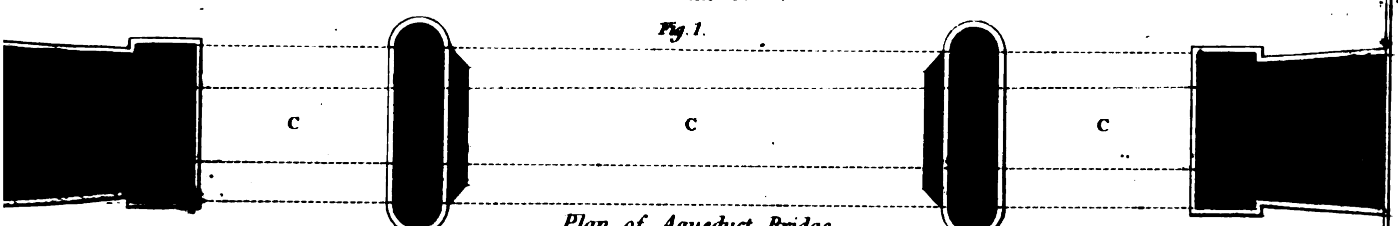
Section of Aqueduct.

Fig. 2.



Elevation.

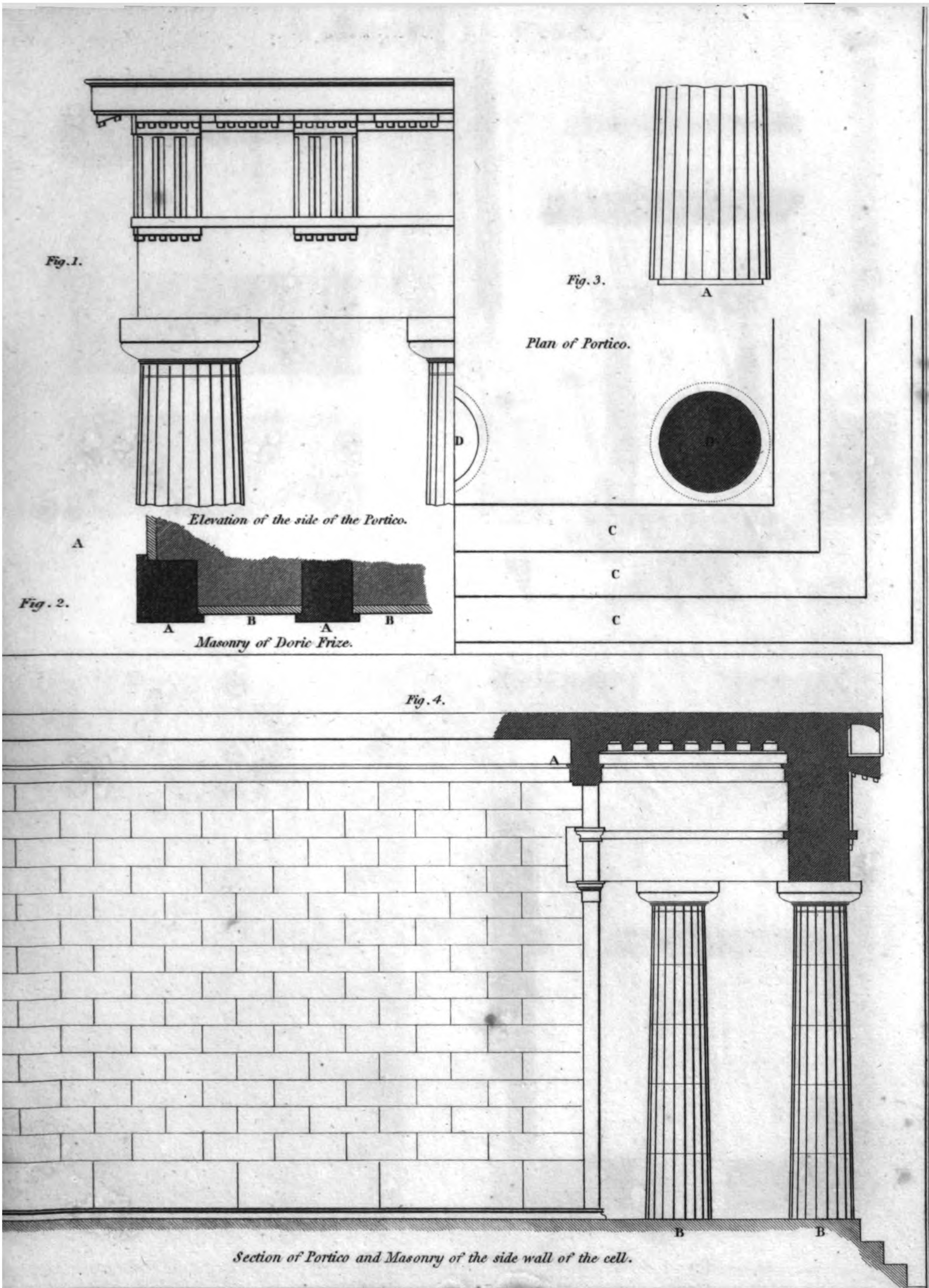
Fig. 1.



Plan of Aqueduct Bridge

Lowry sculp

London. Published by Gale, Curtis & Fenner. & Rees & Curtis, Plymouth. 1811.



Lowry sculp.

London Published 1812 by Gale, Curtis & Fenner, & Rees & Curtis, Plymouth.

MASONRY IN PISÉ.

Fig. 12.

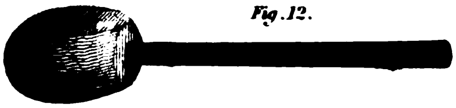


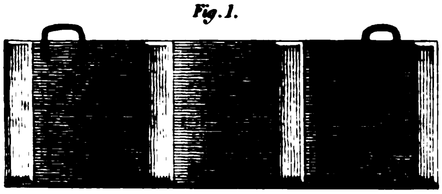
Fig. 8.

Fig. 9.

Fig. 10.

Fig. 7.

Fig. 1.



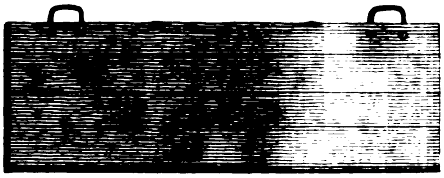


Fig. 2.

Fig. 11.

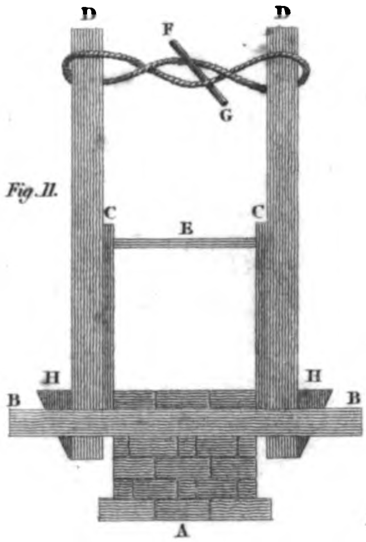


Fig. 4.

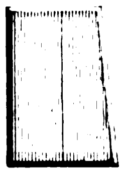


Fig. 3.

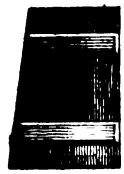
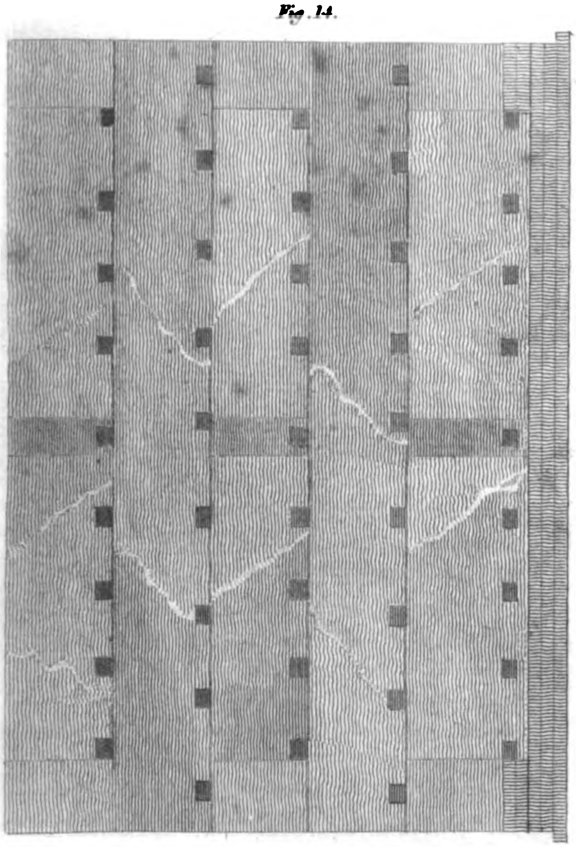


Fig. 5.

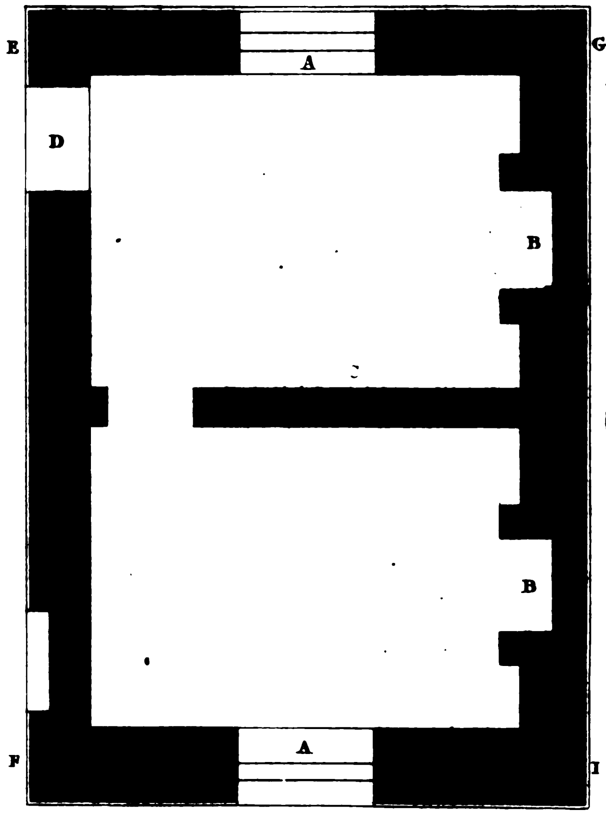
Fig. 6.

Fig. 14.



Elevation of Wall.

Fig. 13.



Plan

London, Published 1815, by Gale, Curtis, & Fenner, & Rees, & Curtis, Plymouth.

Lowry sculp.

MINING.

Mr Taylor's Air Exhauster for Mines.

Fig. 1.

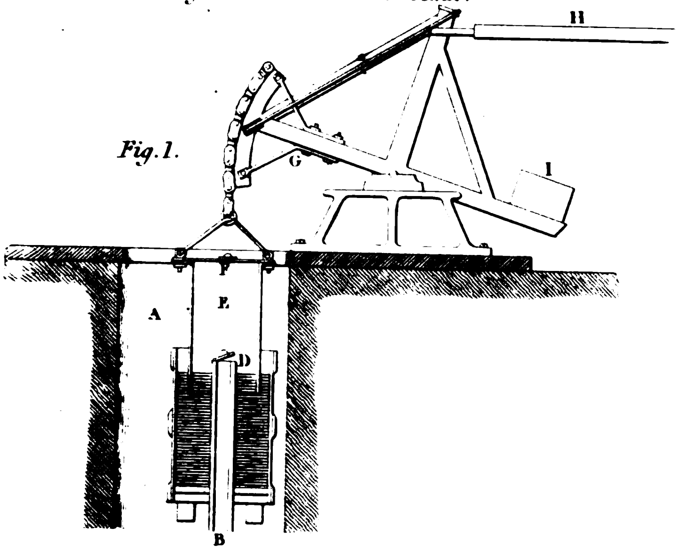
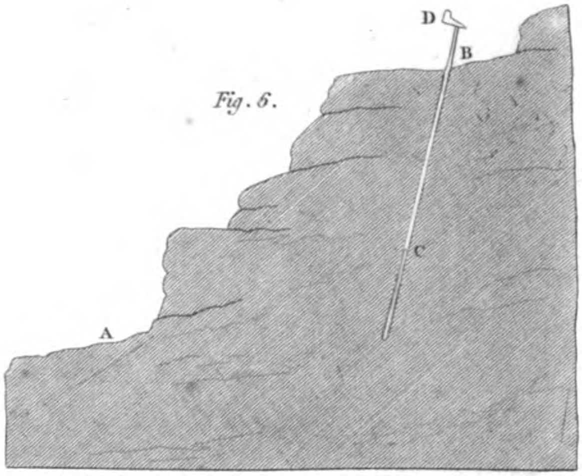


Fig. 6.



Miners Tools

Fig. 2.

Fig. 3.

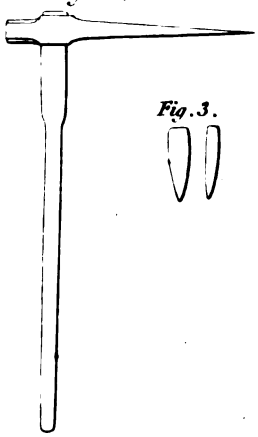


Fig. 4.

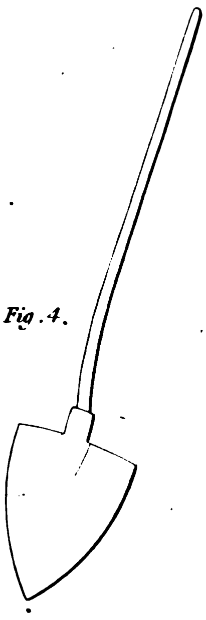


Fig. 5.

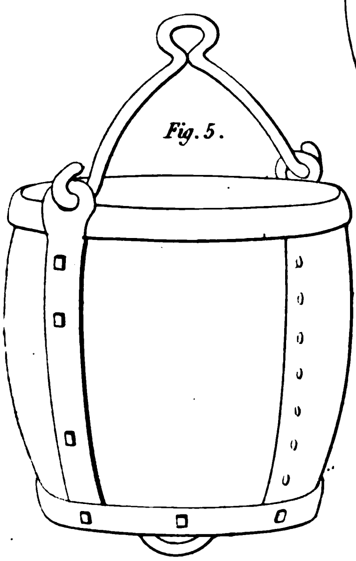


Fig. 7.

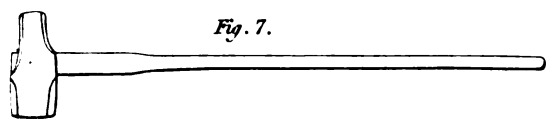
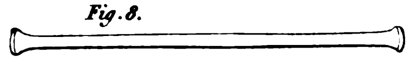


Fig. 8.



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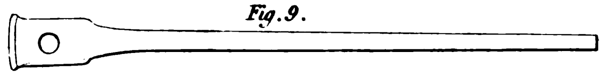

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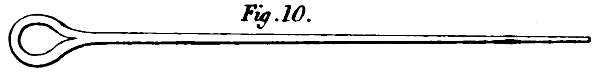

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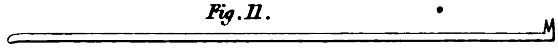
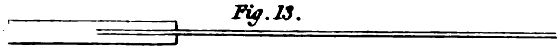


Fig. 12.

Fig. 13.



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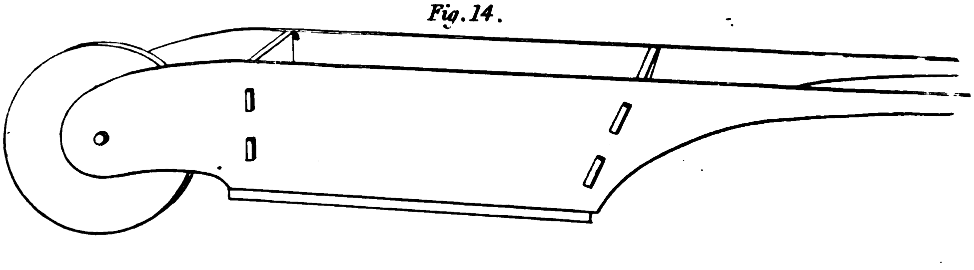

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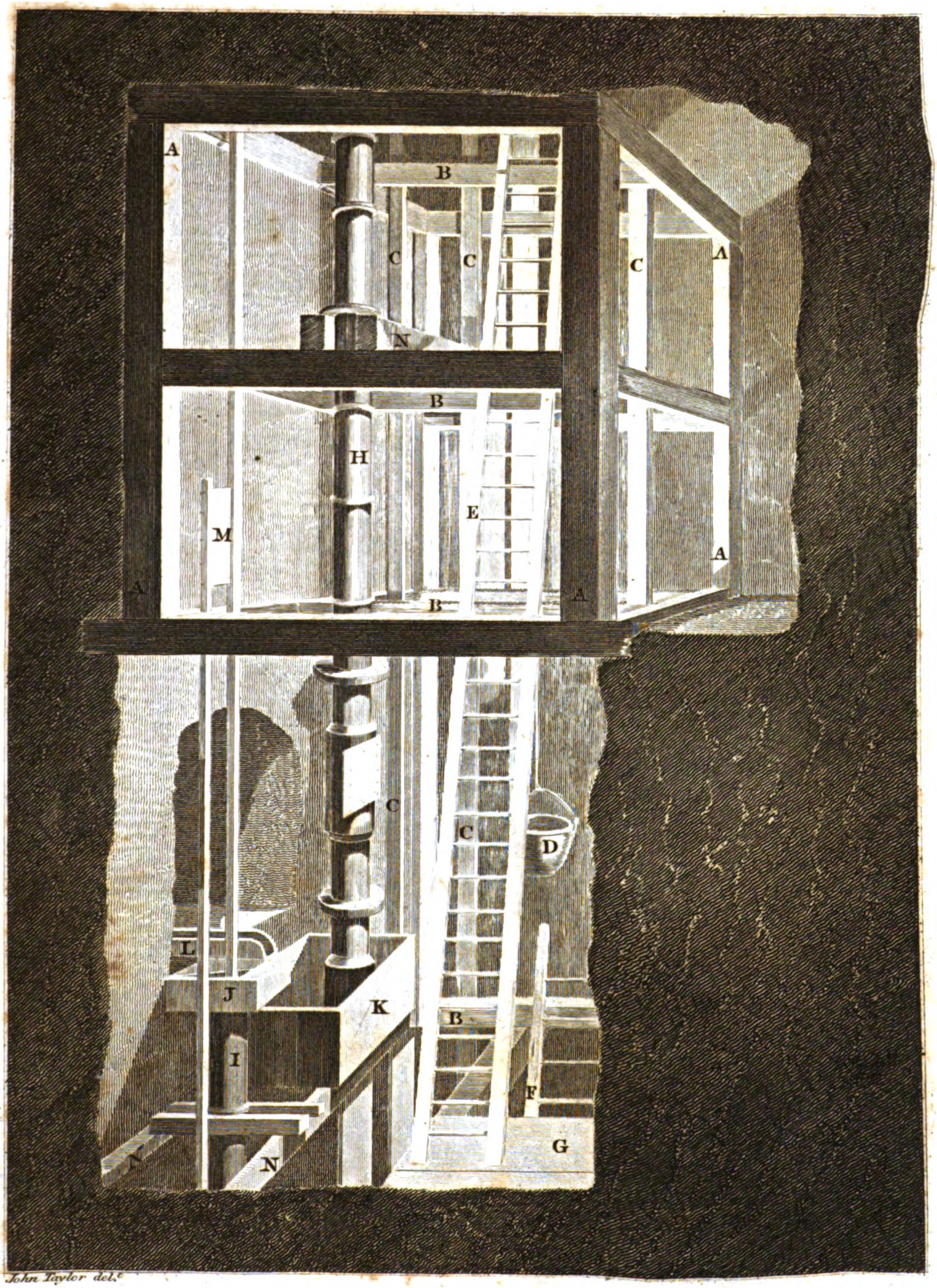

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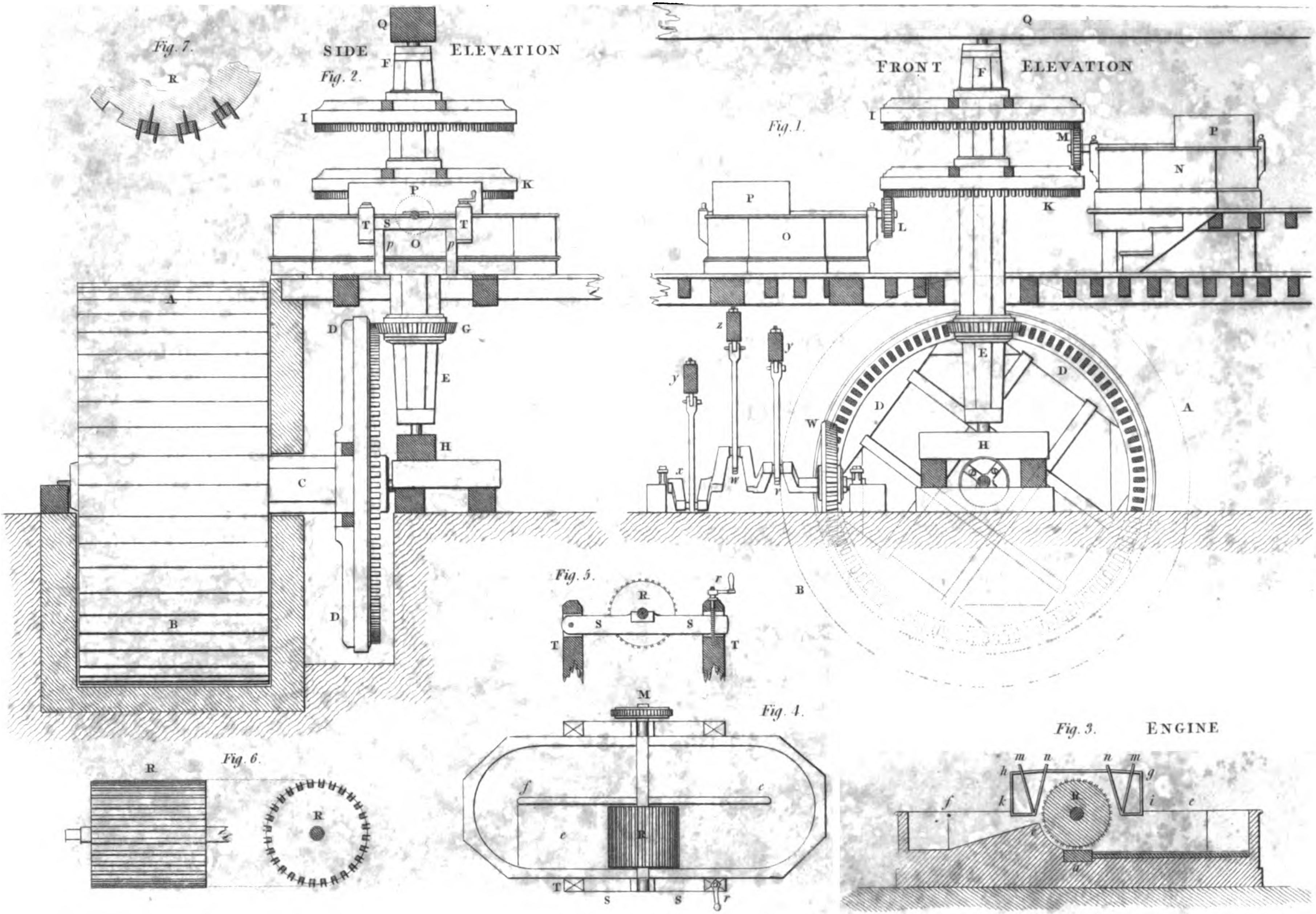

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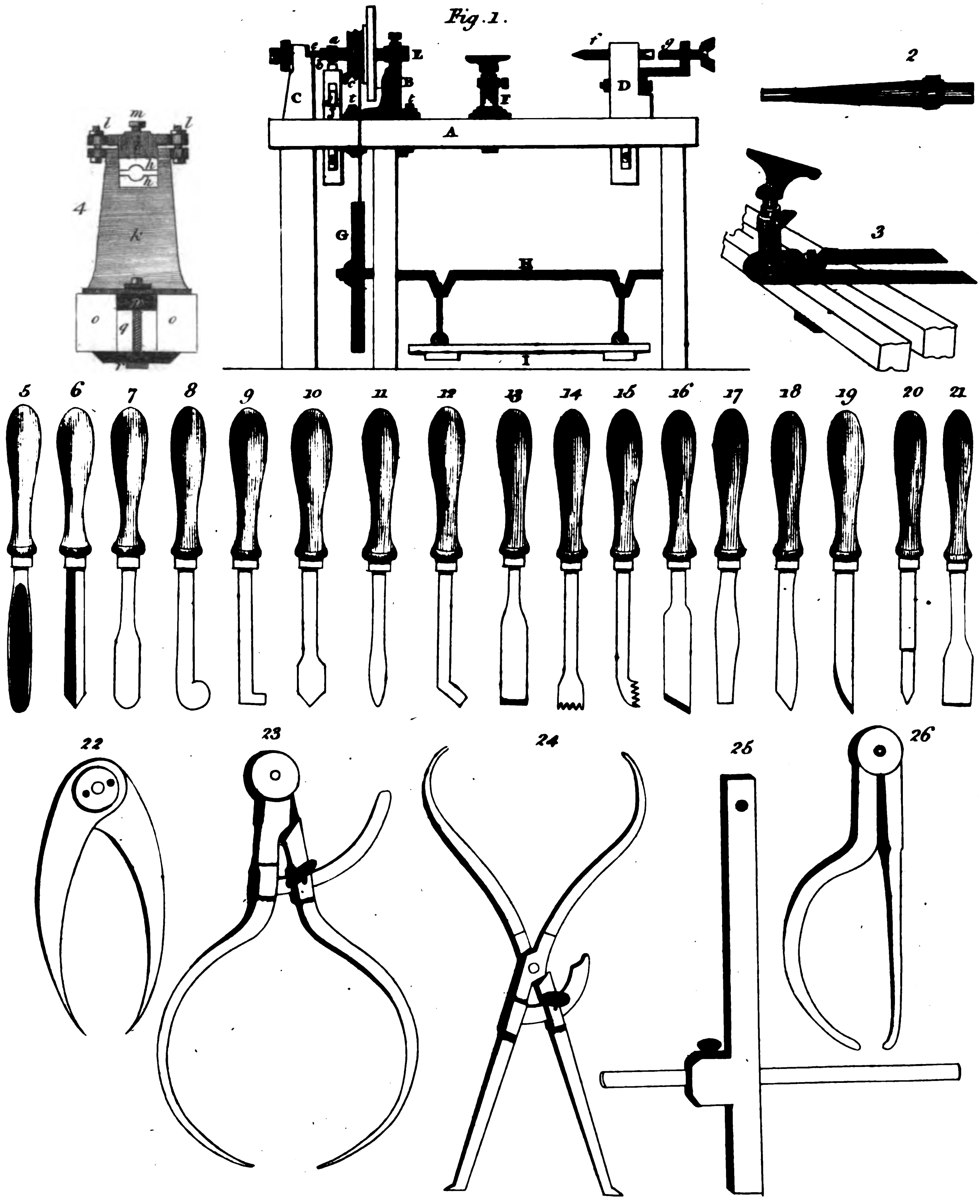
Fig. 1.
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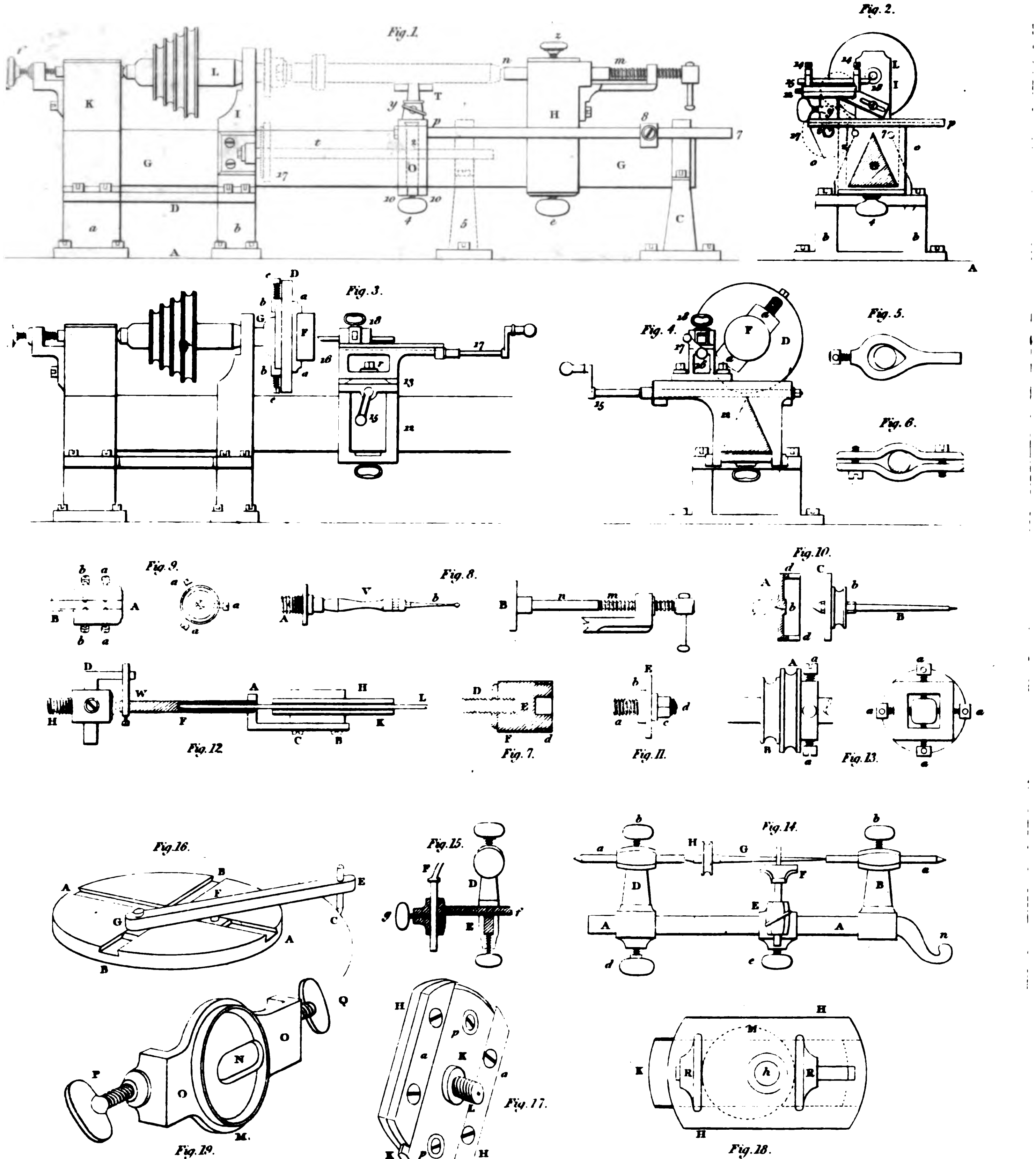

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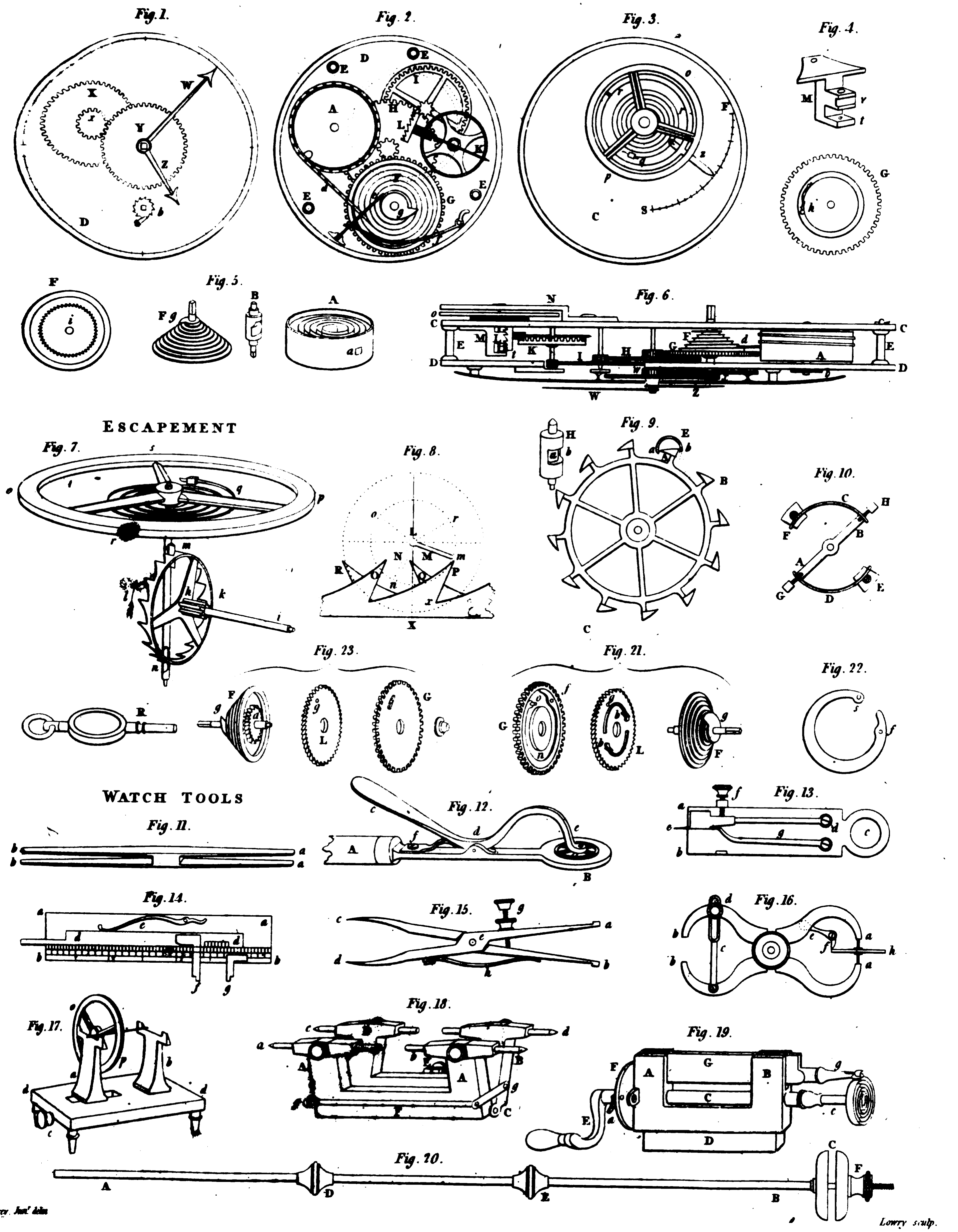
WATCH WORK.



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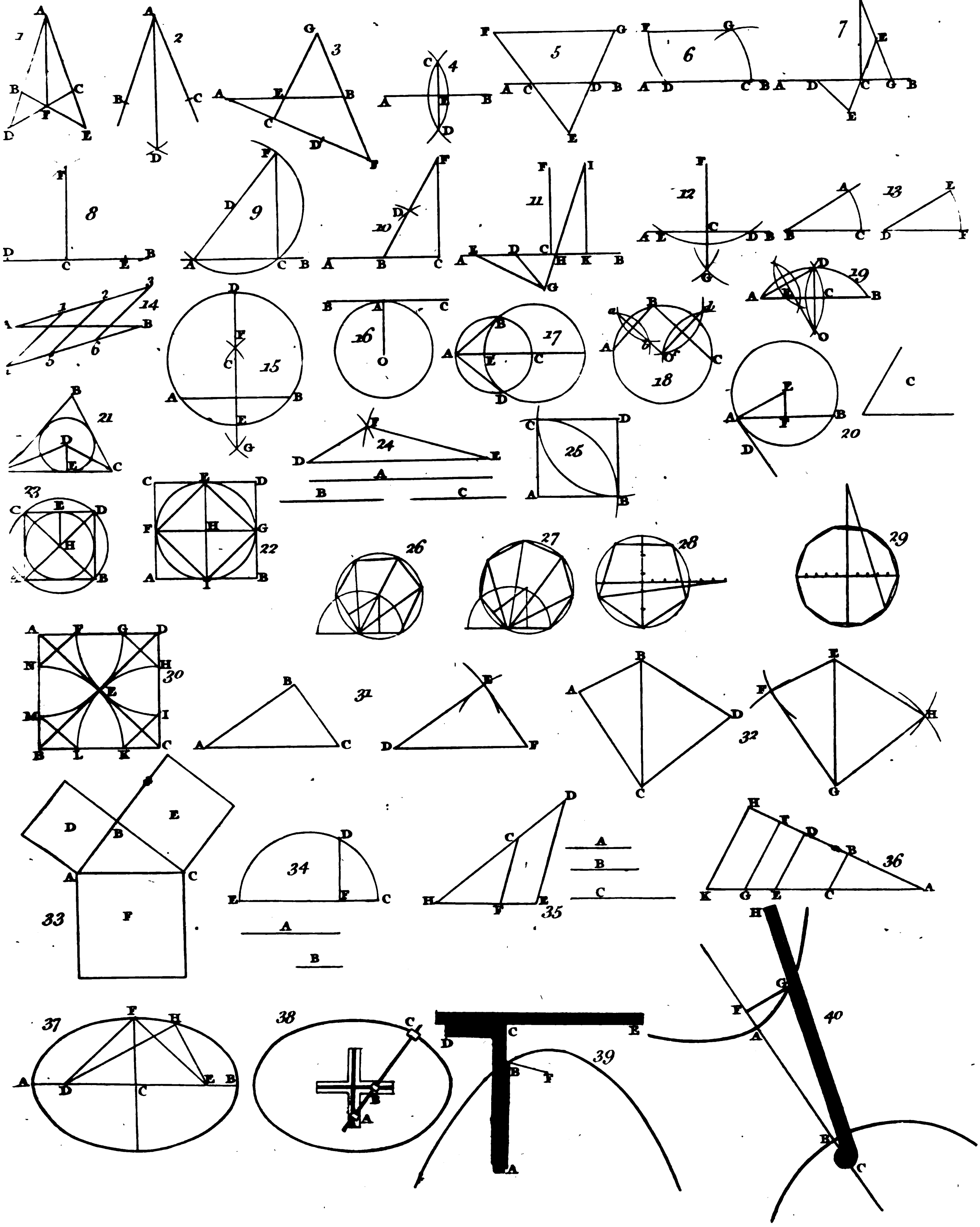
PRACTICAL GEOMETRY.



GEOMETRICAL DEFINITIONS.